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PERCEPTION OF SPACE AND TIME IN OUTER SPACE

by A. A. Leonov and V. I. Lebedev

"Nauka" Press, Moscow, 1968

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MAY 1969

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PERCEPTION OF SPACE AND TIME IN OUTER SPACE

By A. A. Leonov and V. I. Lebedev

Translation of "Vospriyatiye Prostranstva i Vremeni v Kosmose"
"Nauka" Press, Moscow, 1968

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PREFACE

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The characteristic dynamics of a flight of a spacecraft are described in this book, as is the role of astronauts in the "man-spacecraft" system.

The authors describe how the conditions of existence and the psychophysiological mechanisms of perception of space and time outside the Earth change during a flight in outer space. The effect of weightlessness, prolonged isolation in a small area, emotional tension, and other factors of space flight on human perception of time are explained.

One of the authors of this book, Pilot-Astronaut A.A. Leonov, relates the impressions he had when he left the spacecraft and walked freely in outer space.

The future possibilities of training astronauts by orienting them to a prolonged space flight and by organizing periods of work and rest on an interplanetary spacecraft are mentioned.

This book was intended for psychologists, philosophers, biologists, doctors, and other interested specialists studying the problems of space and aviation medicine.

FOREWORD

I call the attention of the reader to the joint work of two authors, Pilot-Astronaut A.A. Leonov and Doctor V.I. Lebedev. The book treats certain psychophysiological problems of the perception of space and time under the conditions of space flight. /5

The beginning of the space era was marked by the launching of the first artificial earth satellite in our country; the ten years since that time have been full of remarkable achievements in the field of the study and conquest of outer space.

Our concepts of the space surrounding us, the Moon, and the planets of the Solar System have expanded immeasurably. Space biology has made outstanding achievements in the study of the characteristics and the nature of the effect of external factors of the outer-space medium and flights on rocket apparatus on various living organisms. The fundamental scientific facts necessary for the development of means and methods by which a manned space flight could be accomplished were accumulated within a remarkably short period of time. The incomparable possibilities for a man to study outer space were soon opened up by Yu. A. Gagarin's first flight on the "Vostok" craft on April 12, 1961.

The subsequent flights of Soviet and American astronauts have provided invaluable scientific data on the physics of outer space as well as the reactions of Man to conditions of a medium which is unfamiliar to him.

However, each new step has produced new problems and presented new and complex tasks to scientists. These definitely include the complex of psychophysiological problems related to a manned flight on a flying spacecraft.

Naturally, the reader will agree that the study of human psychophysiology in itself is an exceptionally complicated field of science. The study of this problem is even more complex under the conditions of a space flight. /6

It is no coincidence that there have arisen a number of doubts in this field: can a man react normally to the unusual conditions of space flight, are his functional potentials preserved, can he perceive the events in the world surrounding him adequately?

The correct solution to these and many other problems had depended on the strategy and tactics of future manned flights and on the general direction of space research.

Yu. A. Gagarin, G.S. Titov and their colleagues have handled with confidence the tasks of maneuvering space apparatus and carrying out the program of scientific studies imposed on them. Moreover, specialists in the field of space medicine have shown judicious caution, and have expanded and deepened their studies of the psychophysiological reactions of astronauts from flight to flight; they have examined what seemed the most insignificant and least noticeable changes in the reactions of the astronauts.

It was of exceptional importance not only to conduct complete studies of the entire phenomenology, but also to establish prognoses for future flights on the basis of a detailed analysis of the reactions found. These predictions are also based on a consideration of the increase of the complexity and duration of space travel.

The authors of this book present the readers with the scientific data accumulated to the present in an acceptable and popular form. They touch upon many problems of human psychophysiology during space flight, but they assign particular importance to the perception of space and the "reading" of time.

This book is not a literary survey of an extensively-developed problem; it is a collection of materials presented in a rather subjective manner. However, the reader will obtain a fairly complete representation of the problem at the contemporary level of knowledge. The authors mention new problems, and they mention interesting and important problems for future searches.

The thoughts and impressions of one of the authors, Pilot-Astronaut A.A. Leonov, who was the first man to leave a spacecraft and walk in outer space, are of unquestionable interest. This gives the book its documentary nature and the freshness of its presentation.

It is possible that the reader will find debatable and doubtful positions or problems which have not been eludicated sufficiently. This is no calamity; we can hope that this book will incite further and more detailed analyses of the very important problem presented here.

Professor O. G. Gazenko,
Corresponding Member of the
Academy of Sciences of the U.S.S.R.

INTRODUCTION

The human mind has discovered much that is remarkable in Nature, and is discovering more and more, thereby increasing its power over it. /7

V. I. Lenin

The orbital flights of Soviet and American astronauts have given witness to the fact that mankind is on the verge of penetrating the depths of the Universe. Naturally, the most immediate stages in the conquest of outer space are a landing on the Moon and flights to certain planets of the Solar System. Such flights are made possible by rockets which operate on chemical fuel, not to mention interplanetary craft with nuclear-energy devices.

In order to carry out such far-reaching plans, it is of primary importance to establish orbital stations around the Earth. This cannot be managed without solving the problems of control in rendezvous and docking maneuvers, repairing metal parts by welding them, and other technological and industrial operations in outer space.

A heavy piloted interplanetary craft and its equipment are a complex multicomponent system of controls managed with the assistance of the pilot. The principal functions of the astronauts include carrying out tasks to regulate the operation of various devices and their complexes, the tasks of cosmic navigation, corrections of the flight trajectory, preparations for landing on some celestial body, etc. Moreover, the crew of an interplanetary craft must conduct a great complex of scientific studies; in particular, they must conduct astronomical observations.

The astronauts must move from place to place on the planet in question, and carry out many different operations under unusual circumstances. Finally, it is necessary to return to an orbit around the Earth, and then descend from it to land on the Earth. /8

All this presupposes that the astronauts will know how to orient themselves in space and time under most unfamiliar conditions. This situation is all the more necessary in view of the numerous examples of flight accidents because of illusory perceptions of the spatial interrelationships of real objects and an inadequate time distribution of actions on the part of the pilot. We can see from this the real significance of analyses of all types of problems related to the possibility of a correct image by a human mind of the space and time characteristics outside the Earth, as well as the realization of such a possibility.

In his work "Materialism and Empiriocriticism", V.I. Lenin wrote: "If the perceptions of time and space can give a man a biologically feasible orientation, it is solely on condition that these perceptions reflect the objective reality outside the man: a man could not adapt biologically to a medium if his senses did not give him an objectively correct representation of it" (Vol. 8, p. 185). It follows from this assumption that a correct image of objects is inseparably connected with an adequate reflection of their space and time aspects and relationships. At the same time, in a critique of the book "The Essence of Religion" by L. Feuerbach, Lenin maintained that man has exactly as many sense organs "as he needs to perceive the world in full, in its entirety". In discussing this book, V.I. Lenin posed the following question: "If man had more senses, would he discover anything beyond what actually exists in the world?" His answer was: "No" (Vol. 29, pp. 51-52). In other words, from the point of view of Marxist epistemology, our sensory apparatus is sufficient for us to recognize the objective truth. However, this conclusion has been based thus far on purely terrestrial materialism. With the establishment and development of practical astronautics, we have found it necessary to test the conclusion in relation to the conditions of outer space.

It is well known that all living beings populating our planet are developed and constantly affected by many specifically terrestrial factors. The factors include primarily the Earth's atmosphere, diurnal and annual periodicity, and certain magnetic and gravitational fields. For example, the force of the Earth's gravity affects not only many physiological functions and the size and shape of animals, but also the psychophysiological mechanisms of perception of the outer world, including the space-time aspects. Thus, the central nervous system of a human being, its structure and function, and particularly its mechanisms for correct perception of the properties of objects in space and time, have been developed and reinforced as a result of long-term evolutionary development under specifically terrestrial conditions, and correspond to them.

However, it is very probable that the sensory (generally /9
psychophysiological) apparatus of living beings necessary for an adequate perception of reality, under completely different conditions of evolutionary development would be constructed in a very different way. According to A. Ye. Magaram (1960, p. 59), V.I. Lenin discussed with him the possibility that there is life on the planets of the Solar System and in other places in the Universe, that intelligent beings could live there, and that these intelligent beings could perceive the world by other sense organs, in relation to the force of gravity of the planet and other conditions.

A detailed analysis of these problems is a matter for the future when the developments of astronautics and many other fields of science and technology will reveal the possibility of a direct study of extraterrestrial forms of living organisms, as well as the possibility of contacts with extraterrestrial civilizations. The task of today is somewhat different, but it has important theoretical and world-outlook significance and a great practical value.

This is the question: how and how much will the psychological apparatus of a human being be ensured an adequate perception of reality (including perception of the time and space aspects) under the conditions of outer space and space flight, to which it has not adapted historically?

In this book, the authors have done their utmost to generalize certain data in the literature, experimental materials, and experiences of orbital flights on spacecraft, which might aid in the finding of an answer to the question we have discussed. We hope that this attempt will attract the attention of many philosophers, psychologists, physiologists and other specialists to the problem in question.

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THE SPACECRAFT AS A CONTROL OBJECT

Personality is always most important; the human personality should be as firm as a rock, since everything is built upon it.

I. S. Turgenev

Before discussing the problems of the orientation of Man in space and time outside the Earth (and under corresponding simulated conditions), it would be logical to discuss, if only briefly, certain characteristics of the dynamics of the flight of spacecraft and the role of the astronaut in the "man-spacecraft" system. /10*

Dynamics of the Flight of Flying Space Apparatus

In steering any means of transportation, we must always keep in mind the medium in which the motion and the forces acting on the control object occur. On the Earth, the friction of the ground or water is very substantial. Because of this, the progressive movement of an automobile, a ship, submarine, etc., will stop quickly "by inertia" after having gone a small distance when the engines are turned off. In discussing the operation of the engine apparatus, it is necessary to investigate the entire course. Calculations show that, for the means of transportation used on the Earth, the energy expenditures increase in proportion to the increase of the length of the course. The inertial forces which must be overcome during acceleration, turning and stopping comprise a small percentage of the total energy expenditure during movement.

During space flight, the principal energy expenditures coincide with inertial forces and gravitation. The problem of friction is important only during flight in the dense layers of the atmosphere. Therefore, the role of the rocket engines is essentially one of transmitting to the spacecraft the velocity necessary for overcoming the gravitation of a planet, as well as putting it in /11
orbit or an interplanetary course, or aiding in landing. After these operations (if we do not consider the landing and the approach to it) the spacecraft moves by inertia, with the engines turned off. This is a flight according to the laws of celestial mechanics, (in particular, Newton's law of universal gravitation).

As the distance from the planet increases, the attractive force acting on the spacecraft diminishes rapidly; as the spacecraft moves closer to another celestial body, the force increases in the same proportion. Obviously, there are a number of points in space

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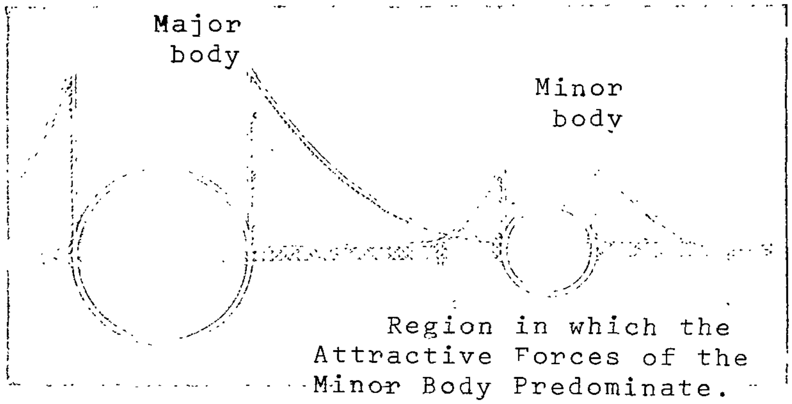
*Numbers in margin indicate pagination in original foreign text.

where the gravitational effect on the spacecraft is identical from both bodies. These points form a definite area which comprises the boundaries of the regions where the pull of one body overcomes the pull of the other. For example, the points of equal forces for the "Earth-Moon" system are 38,321 km from the Moon and 346,079 km from the Earth.



Regions in which the Attractive Forces of Each of Two Gravitationally Interacting Planetary Bodies (in this case, a Major and a Minor Planet) Predominate.

Let us now consider the flight of a spacecraft from the Earth to some planet in the Solar System. Since the craft should have a velocity no less than escape velocity after launching, its movement will occur at first along a parabolic or hyperbolic orbit in relation to the Earth, mainly by the effect of the Earth's gravitational field. Subsequently, the nature of the trajectory will be determined primarily by the force of solar attraction, while the effect of the planets will cause only small distrubances. Finally, as the spacecraft approaches the target planet, the gravitational /12 effect of this planet will become predominant. In general, calculations of the trajectories of a spacecraft are connected with the solution of a very complex problem of several celestial bodies (for instance, Earth - craft - Sun - Venus)[1], and the realization of these flight trajectories require that the astronauts carry out very important operations, despite the abundance of automatic equipment. The tasks imposed on the astronauts would be unthinkable without a fairly adequate space-time orientation.

We should mention that the great velocities of spacecraft in space, the exceptional complexity of the calculations and realization of the flight trajectories, and many other factors have caused

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[1] A more detailed description of the calculations of spacecraft trajectories is given by L.M. Vorob'yev in the book "Navigatsiya kosmicheskikh korabley" ("Navigation of Spacecraft"). Moscow, 1964.

many foreign scientists to treat the possibilities of a man working under these conditions with great skepticism; these factors have also aroused fetishism in relation to automatic apparatus. On the other hand, during the first American orbital space flight, the astronaut (Glenn) was forced to land the craft manually because the automatic equipment had failed. In his report, Glenn emphasized the fact that "a man may have greater responsibilities in steering the spacecraft than had been planned. In many areas, the safe return of a man can depend on his actions. Although such circumstances were not considered in the "Mercury" project, the astronaut never considered himself a passive passenger during this project. Even when automatic systems were necessary, the reliability of their operation was increased considerably due to the presence of the astronaut. The flight on "Friendship-7" is a good example. The craft might not have flown three orbits and returned to the Earth had there not been an astronaut on board". Automatic equipment also failed on the Soviet "Voskhod-2" spacecraft, so that its commander, P.I. Belyayev, had to use manual controls. He oriented the craft rather accurately and turned on the engines' braking devices at the proper time.

These and other facts have shown convincingly that no matter what the degree of automatization on the spacecraft, the directing and organizing role in controlling them remains a human task. This role will become even more important with further, more serious complications of the tasks which will be imposed on the astronauts in relation to the development of the entire complex of studies in the conquest of outer space. The more boldly astronauts travel outside our planet and the further they penetrate cosmic expanses, the more often they will be confronted with unforeseen situations and phenomena which require rapid and correct reactions, including the task of steering the spacecraft. In this case, it is not always possible to obtain the necessary commands, advice, consultations, etc. (timely ones, in particular) from the Earth. Not even con- /13
sidering the completely conceivable cases of interruption or loss of communication between the spacecraft and the ground control center, we must keep in mind that the lapse of time between the moment when information is sent to the Earth and the moment the response is received from the Earth increases in proportion to the distance. This delay is about 2.5 seconds for the Moon, and about 5 minutes for Venus. Moreover, these figures do not include the time needed for working out the response to the questions of the astronauts. Naturally, no cybernetic device can replace the creative intellect and intuition of a human being, without which there can be no solution, even a completely independent and very operative solution, to the problems of maneuvering the spacecraft under unforeseen conditions.

It follows from all we have said that we should not match the automatic apparatus against the man, or the man against the automatic devices; we must find the most rational methods and means of a combined use of human possibilities and automatic techniques.

Combining Man and Machine

The study of the "man-machine" system can be conducted, and is conducted, from different points of view. A very important aspect here is the engineering psychology, the classic example of which is the activity of the man in the control and steering systems, or, more precisely, the interaction between man and machine in such systems.[2] Naturally, we must consider that the work of the latter and the working activity of the former are qualitatively different. Man, who controls Nature, carries out consciously imposed tasks, while the machines are only the "executors" of his will, the instruments of his labor. The psychophysiological processes also differ basically from the processes occurring in automatic devices. Nevertheless, we can find a number of aspects and features which the activity of the man and the operation of the machine have in common; thus, we are able to compare the possibilities of each component of the system.

Let us examine which functions a man, as a link in the steering system, can accomplish better than a machine, and which functions he accomplishes worse than a machine, from the viewpoint of engineering psychology.

In order to maneuver a spacecraft, a man must perceive the surrounding situation rather clearly, interpret the information obtained, and operate the control units of the spacecraft correspondingly. Studies have shown that it takes a certain amount of /14
time for the nerve stimulus to go from the sense organs to the brain. In this respect, it is interesting to mention an event which occurred at the end of the eighteenth century, an event which marked the beginning of the history of the study of psychomotor reactions.

In 1795, the Director of the Greenwich Observatory, Maskelyne, dismissed an astronomer named Kinnbrook because the latter had noted the passage of stars through the meridian half a second late. Maskelyne found the errors in Kinnbrook's observations by comparing Kinnbrook's data with his own, which he considered absolutely trustworthy. However, 30 years after this event, the German astronomer Bessel discovered that all observers, including Maskelyne, were noting the time of the passage of stars through the meridian inaccurately. It was explained that each of them had their own average delay-time. This time is now taken into account in astronomical calculations by a coefficient called the "personal equation".

The time for a simple motor reaction, i.e., the time from the moment the signal appears to the moment of the beginning of the motor response to it, was first measured by Helmholtz in 1850. This time was found to vary for different people (from 0.1 to 0.2 sec). When the experiment was made much more complex, for instance when the subject was to push a button in response to the flashing of one light (out of many) of a certain color, the time of the motor reactions increased substantially (0.5 sec and longer).

The insufficient rapidity of human psychophysiological reactions became particularly noticeable in controlling jet aircraft. When the airspeed exceeds the speed of sound by a factor of two, there is a "blind" spot in front of the aircraft which the pilot does not perceive. Objects in front of the pilot which seem to him to be 100 m away are actually beside him. If two pilots fly toward each other at such a speed, and one of them is emerging from behind clouds, they will not see each other at all at a distance of less than 200 m.

The experience accumulated in aviation and the corresponding experimental materials indicate that it takes 1.5-2 sec to evaluate a normal situation during a flight on a jet aircraft. An orbital spacecraft flies about 16 km in that time. At first glance, it might seem that astronauts cannot react to many events occurring in outer space when they are flying at such a speed, not to mention greater speeds. This is not true at all.

When we look at an embankment from the window of a moving train, we can see only solid lines flowing together. Gradually moving our eyes to further distances from the window, we can distinguish three zones: a zone where all is fused, one where single objects flash into sight, and one where individual objects are seen clearly. The boundary between the first and second zones aids the test pilot in determining the distance to the Earth before landing.

The lower the astronaut flies over the Earth, the less it is possible for him to react to perceived objects. When observing the Earth from a porthole in the craft at an altitude of 200-400 km, the astronaut senses that the Earth is moving slowly. During an interplanetary flight, an astronaut's perception of speed disappears completely. A uniform picture lies before him. In one porthole, he sees bright, non-flickering stars against the background of a sky which is as black as ink; in the other porthole, he sees the blindingly bright disc of the never-setting Sun. Thus, astronauts sense an "excess" of time while the craft moves away from celestial bodies. On the other hand, when approaching some celestial body or the Earth, there is a time "deficit". In these cases, automatic devices are used to aid the astronauts. A special apparatus which senses certain signals from the surrounding medium and transmits the corresponding commands to the slave mechanisms of the craft can accelerate the reaction to a change in the situation by tens and hundreds of times. /15

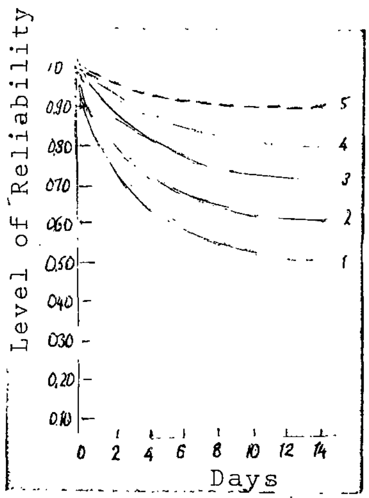
In order to "deliver" some command, the information obtained from the sensing device must be reprocessed. The automatic devices can handle such a task much more rapidly than a man, even when the task is very complex. In the latter case, the machine can draw a whole series of conclusions from definite assumptions, dismissing incorrect conclusions or those which are not best suited to the given situation. Cybernetic devices are also capable of making certain predictions on the basis of the information they have obtained and reprocessed. However, all this can be accomplished only when programs devised by a human being have been introduced into the machine, and when the information in question is included within the scope of the programs. If an automatic device encounters some phenomenon or class of phenomena which was not stipulated in the program, it cannot aid a man at all. A cybernetic machine cannot accomplish such operations accurately by processing information which was not stipulated by its designer. In other words, the great rapidity of a cybernetic device in "sensing" and processing information does not compensate for the insufficient "alertness" and "resourcefulness" of the automatic device, particularly when basically new events, processes, or objects are encountered. Moreover, there must be a particularly large number of such phenomena encountered in outer space. In this case, the superiority is clearly on the side of the human being, who can analyze a situation he has not previously encountered and interpret it correctly.

Another characteristic of a human being is his great flexibility in executing tasks. Using the same motor apparatus, he can carry out very diverse operations. In contrast to a machine, a human being can adapt very well to different commands; moreover, he can improve this quality almost indefinitely by learning (training), while the degree of adaptability of automatic devices depends on /16
its design (and can be increased only insiginficantly). As a rule, the corresponding automatic regulators are very specialized. With a certain degree of training, a human being can accomplish regulating functions as successfully as many automatic regulation systems, no matter how varied their functional and structural designs. He can also change the programs by which the regulations should be made rather easily and frequently. In the case of breakdowns, he is capable of changing the methods by which he accomplishes his functions in the regulation system. The machine ceases to operate in such a situation, or it allows gross errors.

It is true that a human being is subject to fatigue and boredom, which involves a decrease in the quality of his operations in controlling the craft. Such psychological conditions as fear, confusion and panic can lead to an accident or death. Machines do not have these faults. As a rule, they have great reliability in relation to the external medium and its changes. Nevertheless, the use of a human being as an operator in an automatic system is not only advisable, but necessary. This has been confirmed by special experiments.

American researchers have conducted experiments to compare the reliability of operation of systems on board a spacecraft; some systems were completely automated (with two, three, four and five systems to accomplish the same operation); the others were designed to include an operator. At first, the operation of all five systems was identically reliable. However, on the fourth day of the test flight, there was noted a disparity of the reliability curves. At the end of the 14-day period, the reliability of the second, third and fourth systems could not be considered satisfactory, while that of the fifth system was not sufficiently high. At the same time, the reliability of operation of the system which included an astronaut did not change to a great extent; it remained higher than that of the other systems. Moreover, its weight was less than that of the latter; this is very essential for spacecraft, in terms of the very rigid weight limits. From all these indications, it was decided that the use of an astronaut as an operator is the most advantageous, effective, and technically progressive method.

Thus, a human being, aided by different automatic devices, can put a spacecraft into a given orbit, correct the flight trajectory, select the most suitable maneuvers for landing on a celestial body, etc., more accurately and reliably than automatic devices alone. Therefore, we can see the real need for an optimum combination of astronaut and automatic devices, with both included in a single control system. A rational combination of the possibilities /17
of a man and a machine is feasible only when the psychophysiological nature of the operator and the technological characteristics of the automatic devices have been considered during the designing of the spacecraft.



Change in the Reliability of the Control Systems on Spacecraft, Completely Automated (Two, Three, Four and Five Systems to Accomplish the Same Operation: Curves 1-4) and Including an Astronaut (Curve 5).

The Astronaut as the Operator in the "Man-Spacecraft" System.

The occupational work of an astronaut is a variety of operations using highly-automated technical equipment.

All the effects on a spacecraft produced by a man and the systems on board the craft can be divided into two large groups: regulating and maneuvering effects. The goal of the former is to maintain certain parameters (for example, the temperature or pressure in the cabin) within a certain range. The maneuvering effects are intended for carrying out some program (for example, changing the orbit of a craft in a certain region in outer space). In order to give some explanation of this very complex and many-sided system for maneuvering the spacecraft, we will pause briefly to discuss its design.

The "Vostok: spacecraft consists of two principal parts: the /18
cabin, in which the astronaut, the equipment which maintain the con-

conditions for his vital activity, and the landing system are located, and the instrument compartment with the braking engine and certain other devices.

The cabin has three portholes equipped with heat-resistant glass. This allows observations to be made even during the return to the Earth, when the heat shield on the craft begins to burn from the heat in the dense layers of the atmosphere. The portholes can be covered by screens which protect the eyes from direct solar rays.

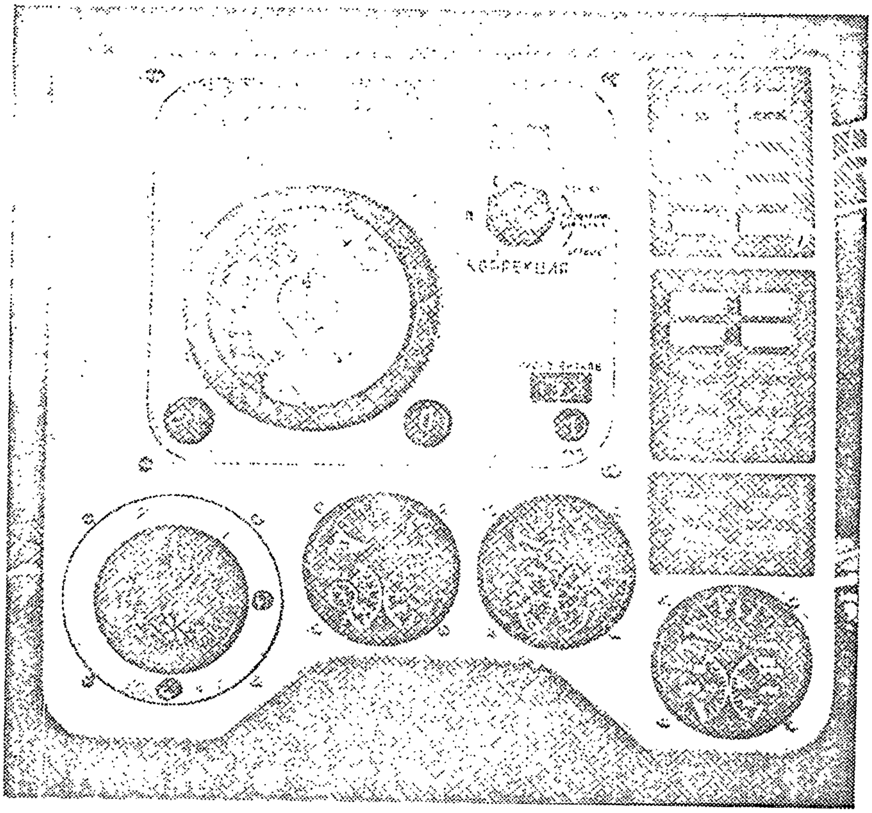
The astronaut is in a special seat which is equipped with an oxygen supply and a device for ventilating the pressurized suit. The surfaces of the seat are lined with soft material, and it is equipped with its own parachute system for catapulting. In order to provide the astronaut with normal air on the craft, there is a system for regeneration and air-conditioning which automatically maintains the given parameters for the percentages of oxygen and carbon dioxide, as well as the temperature and humidity. These parameters can be regulated manually when desired (or when necessary).

The instruments which indicate the humidity, temperature, pressure, and composition of the air are within the astronaut's field of vision on the instrument panel. There are also warning signals, transparent inscriptions which flash during the transmission of commands, signs of trouble, etc. The device which indicates the location of the craft and the landing site is separated from all the other instruments on the panel. It is a glove which rotates relative to two axes at a speed corresponding to the speed at which the Earth rotates, and the angular velocity of the movement of the craft in the plane of the orbit relative to our planet. With this instrument, the astronaut can know his location at any moment, and can determine the landing site at the prescribed time, when the braking engine is turned on.

Thus, the indicating and signaling devices provide the astronaut with the necessary information about the flight regime of the craft and the operation of its systems.

The system for steering the craft includes an information panel (i.e., instrument panel), a control panel, and a system of automatic regulation (SAR) (see the schematic diagram below). The dashed lines on the schematic diagram show the controlling effects on the object and the flows of information about their results (the units are turned on, off, etc.). The solid lines signify the regulating effects, as well as the transfer of information about changes in the regulated parameters. In this system, the regulating functions are accomplished automatically under normal flight conditions. The corresponding information is transmitted to the instrument panel. However, since it usually does not require responsive reactions from the operator, it seems to lose its signaling role. Moreover, it has a very monotonous character. However, /19
when the SAR does not maintain the parameters on the necessary

level, the operator must interfere and participate actively in the control system.

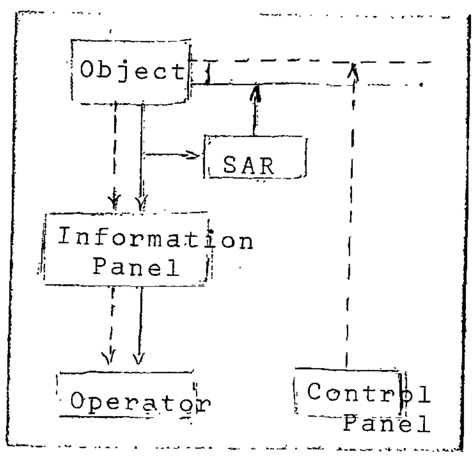


Instrument Panel of the "Vostok" Spacecraft.

On the control desk, there are toggle switches and controls for controlling the screens and filters of the portholes, regulating the temperature and humidity in the cabin, etc., as well as a control stick for orienting the craft, and a circuit switch for the manual controls and the braking engine.

Accurate orientation of the spacecraft in space, as well as /20
its stabilization in a definite position, are necessary for a successful return to Earth. Otherwise, the flight orbit can change undesirably when the braking engine apparatus is turned on, and the spacecraft may be converted into a satellite of our planet. The orientation and stabilization of the craft are carried out automatically, but can be accomplished by the astronaut (when desired, or when the automatic devices break down). It is well known that G.S. Titov was the first to orient a spacecraft in flight manually. This is what he had to say about this circumstance in his report: "After an hour of flight, penetrating the darkest of nights, I

turned on the manual controls on the craft, as was planned. I must admit that this was not done without internal agitation: no other man in the world had been required to subject a spacecraft to his will. 'Will it obey the movements of my hand?', I wondered, and I resolutely put my hand on the control panel. The 'Vostok 2' submitted to my desires. It was easy to control the spacecraft. It could be oriented in any position."



Schematic Diagram of the Control of the "Vostok" Craft.

Naturally, the astronaut continually carries out the proper functions with manual controls. Each signal of a divergence from a given parameter calls for a direct response from the operator. The effectiveness of the astronaut's work is constantly tested and corrected by the principle of feedback, i.e., by those changes which /21 are effected by this work.

The system for manual orientation of the "Vostok" craft consists of an optical sight, a control stick which guarantees control along three axes (path, pitching, and banking), sensors of the angular velocity, and other elements.

The astronaut determines the position of the craft in relation to the Earth through the optical sight. This instrument is placed in one of the portholes of the cabin. With a correct orientation of the craft relative to the vertical, the astronaut sees an image of the horizon in the form of a ring. Through the central part of the porthole, he sees part of the Earth's surface below him. The position of the longitudinal axis of the craft relative to the direction of the flight is determined according to the "movement" of the Earth's surface in the field of vision of the sight.

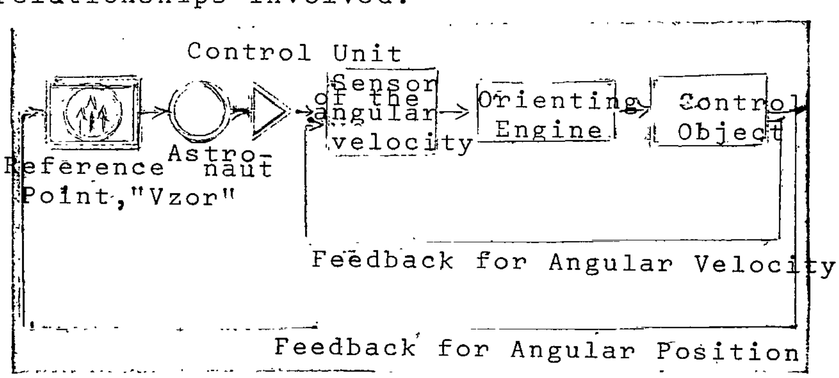
During a digression from the vertical, as well as during a digression of the longitudinal axis of the craft from the direction of the flight, the astronaut uses the control stick and sends commands to the input section of the data units of the angular velocity. The latter formulate signals which are transmitted to the jet engines for orientation, and turn them on. As a result, the craft rotates. As soon as its speed reaches the prescribed value, the engine is turned off, and turning continues by inertia. When the craft reaches the prescribed position, the astronaut releases the control stick. This produces a directional signal which turns on a jet engine for a decrease in the rate of rotation. When it has decreased to the necessary level, the engine is turned off.

From the psychophysiological point of view, the process of manual control by the angular position of the craft differs greatly from a similar operation performed by a pilot in an aircraft. An aircraft reacts comparatively more rapidly to controls, while a spacecraft has significant inertia. This produces the need for developing particular skills in an astronaut by special training. /22

Experiments are now being conducted in which spacecraft are made to rendezvous and dock in outer space. Development of this operation will aid in putting individual sections of heavy interplanetary craft into a docking orbit, as well as orbiting stations, to assemble them. On the other hand, maneuvering a spacecraft in the process of rendezvous or docking differs greatly from the maneuvering of any aircraft. The astronaut must consider that forces of an aerodynamic origin do not act in outer space. If one spacecraft must overtake another, it must be remembered that turning on the engine on the first craft can lead to an increase of its speed as well as a change of its orbit. As a result, the overtaking craft will pass by the object which it was to approach. To state it more briefly, the process of steering a spacecraft and the corresponding skills of the astronaut must differ in many ways from those of an aircraft pilot. Moreover, the shortest way to approach an object can be a curve (not a straight line). At the same time, it is necessary to use a system of coordinates which differ from those used on Earth when the craft is a great distance from our planet.

The astronaut's role is particularly important during the last segment of the docking process, when he must use the manual controls. The speed of the craft should not exceed several meters per second in relation to the docking object (for a shock-free docking), but the process must be accomplished with a force sufficient for triggering the docking locks. Naturally, the spacecraft must be reoriented relative to the docking locks.

Thus, an analysis of the many working operations of an astronaut shows that he must control different systems in a spacecraft, as well as the spacecraft itself (under unusual conditions and when carrying out unusual tasks and operations). This is inconceivable without an adequate perception of the space and time relationships involved.



Block-Diagram of the System of Manual Orientation of the "Vostok" Craft.

ORIENTATION OF MAN IN OUTER SPACE

They felt blissful peace and quiet. The position and direction of their bodies in the rocket was indefinable. It was what they wanted.

K. E. Tsiolkovskiy

In the philosophical sense, time and space are attributes of matter. "There is nothing in the world but moving matter", V.I. Lenin wrote, "and moving matter cannot move otherwise than in space and time" (Vol. 18, p. 181). The latter as well as the former are equally objective, exist outside of, and independently of, consciousness, and are perpetual, infinite, and unlimited. In other words, space and time are absolute from the point of view of philosophy. At the same time, since they are attributes of matter, they each have a certain specificity. As F. Engels has said, being in space means existing "in the form of a position, one beside another", and being in time means existing "in the form of a sequence, one after another" ("Dialections of Nature", p. 9). Space has three dimensions, while time has one. /23

The three-dimensional quality of space (we will discuss Euclidian space for the sake of simplicity) involves the fact that three and only three straight lines perpendicular to each other can be drawn through a given point. The position of any point is determined completely by the indication of its three distances to three intersecting planes selected as the reference system. As for the unidimensionality of time, this means that any moment of time corresponding to the beginning, end, or intermediate stage of any process is determined by one number which expresses the magnitude of the time interval from one moment, taken as the beginning of the reference system, to another moment.

We can move bodies in space from right to left, from left to right, from above to below and below to above, etc. In time, all events occur only from the past, through the present, to the future. Time is irreversible, and it differs from space in this characteristic, also.

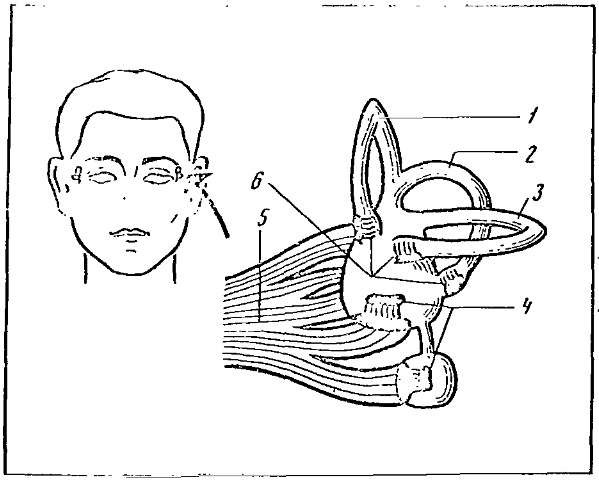
The dialectical unanimity and contradictoriness of space and time as attributes of matter are also reflected in the sensory apparatus of Man. On the one hand, the processes of perceiving spatial and temporal aspects are closely interrelated and mutually dependent. On the other hand, both processes of perception are accomplished by specific functional systems of the cerebrum which are highly differentiated. This has been confirmed in experiments as well as in numerous clinical observations of subjects whose heads had been injured or who had tumors or other illnesses. The /24 existence of such a differentiation is reason enough to discuss the problems of perception of time and space under different headings (although, naturally, we will also mention the interactions of these processes). Let us begin with a brief characterization of the psychophysiological mechanisms of perception of spatial attributes by Man under normal (i.e., terrestrial) conditions.

Psychophysiological Mechanisms of Spatial Orientation

By "spatial orientation under the conditions of our planet", we mean the ability of human beings and animals to evaluate their position relative to the direction of the force of gravity and relative to various surrounding objects. Both components of such an orientation are closely connected to each other, in terms of their functions. However, as G.L. Komendantov has correctly stated, their interrelationships are not identical. While the first component can exist in many cases when isolated from the second, the second component is always dependent on the first. In accordance with these two components of space orientation, we can also single out the psychophysiological mechanisms carrying out their own functions.

From the point of view of physiological and psychological concepts, the ability of a human being to perceive the position of his body in relation to the plane of the Earth, and to perceive the arrangement of objects of the external world in relation to one another and to himself, is not due to the specific activity of any one analyzer, but depends on all the analyzers, including the exterocepters and the interceptors.

Reflection of the spatial position of the body relative to the plane of the Earth (the first component of spatial orientation) is accomplished constantly with the aid of the visual (optical), stato-kinetic (vestibular), proprioceptive (musculo-articular sensitivity), dermato-mechanical, and interoceptive analyzers. Adequate stimuli of the corresponding receptors are the following: light energy (for the optical analyzer) and mechanical energy (for the remaining receptors).



Schematic Diagram of the Vestibular Apparatus (1), (2), and (3) Semicircular Canals (Vertical, Frontal, and Horizontal); (4) Otoliths; (5) Vestibular Nerve; (6) Sensory Hairs.

The vestibular analyzer is one of the principal analyzers of /25 the first component. It is a single system consisting of a peripheral sensory apparatus, conducting nerves, and a central section with nuclei in the brain stem and a region with cells in the cortex. The sensory apparatus is subdivided into the semicircular canals and the otolith apparatus in the temporal bone. The three semicircular canals are located in three mutually perpendicular planes, and are filled with a fluid (endolymph). There are small saccules containing the sensitive endings of the vestibular nerve at the origin of each canaliculus.

In 1878, the famous Petersburg physiologist I.F. Tsion first explained the significance of the semicircular canals in the formation of human concepts concerning space. "The semicircular canals", he wrote, "are peripheral organs of the space sense, i.e., sensations brought about by stimulation of the nerve endings in the ampules; they form the basis of our understanding of the three dimensions of space" (cited by Zimmerman, 1952, p. 41). The mechanism of these stimuli is connected with the laws of inertia. When the head is immobile, or moves in a straight line or uniformly with the /26 body, the endolymph remains immobile in relation to it. On the other hand, if the head is turned or inclined, the fluid in the corresponding canaliculi begins to squeeze out toward the side opposite the turn or inclination. This causes stimulation of the endings of the vestibular nerve, and definite information about what has occurred appears in the form of nerve impulses in the brain.

The otolith apparatus is essentially a gravity sensor which is adapted to transmit information to the brain, mainly during a change in the force of gravity. The principle of its action is also rather simple. The bottom of a small follicle is covered with sensitive nerve cells equipped with fibers, on which calcium salt crystals (otoliths) seem to be lying in a gelatinous fluid. Under the effect of the force of gravity, they press on the endings of the vestibular nerve, causing stimulation of the latter, during which the flow of nerve impulses informs the brain about the magnitude of the pressure. It is easily understandable that this magnitude will change during a rapid ascent of descent. The sensations arising as a result are well known to people who use high-speed elevators.

Kreidel's experiment shows the great significance of the otolith apparatus in the orientation of animals. He extracted the otoliths from the cavity of the otolith apparatus of a young crayfish and replaced them with iron filings. After this, the animal maintained correct orientation in space, and swam with its back up, as always. On the other hand, when the experimenter brought a magnet close to the crayfish, the animal's position changed instantaneously in correspondence with the lines of force of the magnetic field. If the magnet was held above it, the crayfish flipped over, with its back down; if the magnet was put to one side, the crayfish flipped over to the side.

The vestibular analyzer is closely connected with the optical organ, whose role in spatial orientation will be discussed in more detail below. If we spin around in one spot for a long time, i.e., cause stimulation of the vestibular apparatus, and then stop, we will have an optical illusion, sensing that all the objects around us are spinning around. On the other hand, the optical organs affect the vestibular analyzer. This can be illustrated by the following experiment. While looking at a panoramic movie film, a pilot was seated in a chair with an unstable bearing, on which he balanced himself easily, not losing equilibrium, until the beginning of the experiment. He maintained this posture while an aircraft "flew" on the screen, together with the viewer, in a horizontal flight. However, when the aircraft made sharp turns, the pilot's equilibrium rapidly broke down, and he "fell" together with the chair. We also know of certain people who watch the rocking of a boat on waves, etc., on a movie screen and begin to sense the rocking, even becoming sea-sick.

During the course of evolution, the Earth's attractive force /27
has played an important role in the formation of the supporting skeleton and the musculature of living beings, as well as in the development of the so-called muscular sense, i.e., proprioceptive sensitivity. As I.M. Sechenov has shown, it would be impossible to perform any motor act with closed eyes without musculo-articular sensations, or without feedback (in the language of cybernetics). The information transmitted from the musculo-articular apparatus, which supports the body in a certain position, allows a human being to maintain his position relative to the plane of the Earth.

Certain information about a change in the weight and position of the body in space is also provided by the sensitivity of the skin to mechanical stimuli. For example, when a man is standing, the corresponding signals come from the skin of his feet; when he is lying down, they come from the skin of his back, etc.

The receptors which are located in the walls of the blood vessels and which sense the blood pressure are also an "indicator" of the direction of the force of gravity. When a man is standing, the flow of the blood accumulating in the lower parts of the body causes great tension in the walls of the vessels in the lower extremities and a corresponding change in the information transmitted to the brain. Other interoceptors also signal a change in the direction of the force of gravity.

As the studies of B.G. Anan'yev, E. Sh. Ayrapet'yanets and others have shown, the activity of the above-mentioned analyzers is synthesized by certain structures in the cerebral cortex. As a result, there is a definite functional system which reflects the entire situation and thereby allows a correct orientation of the body in space, in relation to the force of gravity. The solution to this problem is also connected with a conscious reflection of the "body structure", i.e., the principal qualities and functional capacities of individual parts and organs in the body, as well as the entire body. In other words, this structure includes the shape, the absolute and relative value of different parts of the organism, their interrelationships, the possible movements of the extremities, general sizes, and the weight of the entire body.

V. M. Bekhterev connected the orientation of an organism relative to the plane of the Earth (or the attractive force of gravity) very closely with the function of equilibrium (in addition to the other functions). In performing any act, a human being moves in space, maintaining equilibrium, and thereby keeping a vertical position relative to the Earth's surface. It is true that, during any act, change of position, or physical work, the position of the center of gravity of the body relative to the reference plane changes, and the conditions for stability are destroyed. On the other hand, the disturbed equilibrium is recovered by means of a compensating move- /28
ment (for example, bending the body, putting one's hands to one side, etc.).

In walking, for example, a person actively moves his center of gravity beyond the reference area, and seems to "catch up" with the foot put forward. Thus, he selects the optimal movement regime in order to maintain equilibrium. This is also characteristic of all other forms of human activity related to the need for assuming a working position and preserving stability.

Equilibrium is preserved, even when a man is standing still, by the continuous functioning of the muscles. The smaller the supporting area, the greater the amount of work his muscles must perform.

The cerebral regulation of the muscles which aid in maintaining a certain position is usually not a conscious operation. When there is a loss of equilibrium, and an urgent reaction of an organism is necessary, the corresponding signals go to the cerebral cortex in a unified form. In this case, the "command" to certain groups of muscles to balance the body relative to the supporting area is often given before a person can realize what has happened. Thus, if someone slips with one foot on ice and begins to fall in the direction of the sliding foot, the immediate reflex of his entire body is to incline toward the opposite side, his center of gravity is shifted, and his equilibrium is restored. This reflex is accomplished by the motor apparatus, but the signals for the "triggering" of the latter are the vestibular and musculo-articular sensations. In general, the reflexes to maintain a vertical position which are brought about with the aid of the vestibular analyzer, the musculo-articular sensitivity and other receptors oppose the effect of the Earth's attractive force on the mass of the body.

The second component of spatial orientation, i.e., orientation relative to the objects surrounding a person, is always accomplished on the basis (against the background) of the first component (as we have already mentioned). This orientation occurs with the aid of a special system of analyzers which includes the optical, auditory, and chemical (olfactory) analyzers. Their receptors are capable of long-range operation. Having an exceptionally high sensitivity to adequate stimuli, they are capable of differentiating the sources of energy fluxes acting on them from great distances.

The most important analyzer for orientation in space is the optical analyzer. During the process of evolutionary development, it has become adapted, not to the direct effect of solar rays, but to the perception of light reflected from various objects. One of the most important characteristics of the optical analyzer is the fact that the sensations arising during its activity seem to be projected toward the external medium. K. Marx wrote that "...the effect of the light from a substance on the optical nerve is perceived, not as a subjective stimulation of the optical nerve itself, but as /29 an objective form of the substance, outside the eyes" ("Das Kapital", Vol. I, p. 78).

Such a characteristic is not a congenital property as is, say, sensation of pain, but is developed during the process of individual practice. "In respect to this", I.M. Sechenov wrote, "it is extremely instructive to listen to the stories of people who were congenitally blind, but whose sight developed when they were adults, when they see the surrounding world during the first days after the operation. Despite the fact that these people had clear concepts in mind about the spatial aspects of the objects surrounding them, and intuitions developed by the sense of touch, they felt that the entire field of vision was somehow filled completely and seemed to touch their eyes, and they were even afraid of moving, for fear of bumping into some object" (1952, Vol. I, p. 220). This effect of "projecting" an optical image onto the objective surroundings was caused by its impression on the retina and by the constant operation of the musculo-motor apparatus of the eyes.

Perception of the shape, size, and movement of an object, and certain other properties of its surface, is achieved by regulation of the complex functional systems of inter-analyzer (as well as intra-analyzer) links. For example, on the basis of only one image on the retina of an eye, we cannot determine the size of the object, since the dimensions of this image depend on the distance to the object. On the other hand, we can see the object from various distances by means of a corresponding contraction (or weakening) of the eye muscles, which changes the shape of the crystalline lens and permits a correct focusing on the retina of the rays of light passing through the object. To sum it up, a determination of the size of an object is made possible by regulation of the conditioned-reflex relationships between the retina and the eye muscles (or, more precisely, accommodating muscles), i.e., between the sensory and motor areas of the optical analyzer.

Perception of depth is also achieved by a change in the convergence (information of the visual axes of the eyes) in relation to the distance. It is well known that the differences between the images of external objects reflected on the retinas of the two eyes result from the non-identical positions of the eyes. Since the centers of the projections of both visual organs do not coincide, and are divided by an intervening space, the same point or detail in the images will be found on so-called disparate (and not identical) points of the retinas. With a great degree of disparity, the objects observed have a "double image". If the disparity does not exceed a certain value, the perception of depth is much better than what would be obtained by observations with only one eye.

People do not usually notice the sensations entering the brain /30 from the accommodating and oculomotor muscles. These proprioceptive sensations can be noticed rather clearly when we move our forefinger slowly toward our nose and then away from it. In this case, there arise musculo-motor interoceptive stimuli related to convergence and accommodation.

Perception of volume, as B.G. Anan'yev has validly stated, cannot be explained only by the activity of the central region of the optical analyzer (i.e., the corresponding sections of the cerebral cortex). The essence of this perception is also connected with some recurring objective relationship between the receptor and the image of the object on its plane ("screen"). In relation to this, Anan'yev has written the following: "It is obvious that a process such as an optical sensation not only begins in the eye but also ends there. This assumption requires acknowledgement of the fact that a sense organ is alternately a receptor and an effector. We must also assume that there is a direct (centripetal) as well as a reverse (centrifugal) relationship between the receptor and the brain" (1961, p. 52).

The principle of feedback was discovered by I. M. Sechenov. In respect to spatial vision, he showed that the optical apparatus of the eye is very closely connected with the oculomotor apparatus. Moreover, in developing his ideas about space, Sechenov attributed particular significance to the sence of touch. The complex dynamics of tactile and muscular sensitivity are always connected with an active process of touch. I. M. Sechenov considered "looking" to be "completely similar in sense" to feeling with one's hands. Developing this concept, A.N. Leont'yev said: "The movement of a hand carrying out a practical contact, an 'actual encounter' with an external object, is necessarily subject to the properties of the object; feeling an object, the hand reproduces it, tracing its markings, its size and shape, and, through the signals coming from the motor apparatus of the hand, its 'copy' is formulated in the brain" (1965, p. 153).

Formation of the conditioned-reflex relationships between the feeling of objects with the hand and the movement of the eyes begins in early childhood. The "retina of a trained eye" is actually the retina of an eye which was first taught by the hand. On the basis of these conditioned-reflex relationships, a small child will develop his spatial vision. As a consequence, a grown man will know how to link visual sensations with movements of the eyes, without moving hands to investigate. According to A.L. Yarbus, in looking as some object, the eyeball moves abruptly in correspondence with the shape of the object. This movement is the most important component of visual perception. In this case, each point of the contour reflected on the periphery of the retina is a signalling stimulus which "pro- /31 pels" the eyes to the position in which the best field of vision is aimed toward the contour line. Thus, the complex synthesis of the visual stimuli (unification of sensations) is accomplished on the basis of the reflex processes.

In correspondence with Sechenov's concepts, Leont'yev described the cognitive function of the hand and the eye as an automatic afferent process similar to the mechanism of servo devices "clinging" to an object. "Due to this, the hand running over the contour of the object does not separate from it, and the eyes are not wasted in examining its individual elements. The contact between the hand and the object gives its movement an origin and a direction; this determines the subsequent signals coming from the object. At the same time, the process of probing or examining is entirely and rigidly dependent on the properties of the object under study" (Leont'yev, 1965, p. 172). In its structure, this process is a circle of reflexs. On the other hand, the latter is a closed circle only in the morphophysiological sense; from the point of view of determination of the reflection, the circle is broken at the "points of contact" with the object. "Something similar occurs, for example, when a soft rubber tire rolls freely over hard objects: it preserves its ring-shaped structure and its mode of rolling movement but, coming into contact with other objects, it changes its configuration and thereby gives an adequate dynamic copy of the objects: (Leont'yev, 1965, p. 173). A "Copy" is also made of an object during the process of tactile or visual reception, but this is not done according to the change in the shape of the "copying" substratum itself; it is done according to the change of the process. The probing hand and examining eye in themselves, do not reproduce the "copy"; their movements play the principal role in this case.

V.M. Bekhterev stated that maintenance of a vertical position, as well as the kinesthetic sensations from movements of a probing hand and an examining eye, is a very important factor in spatial vision. Subsequently, A.A. Ukhtomskiy showed that temporal relationships are established between the general arrangement of the body in relation to the plane of the horizon and the arrangements of the eyes themselves when determining the position of an object in space. These studies were continued by Anan'yev. It was found that the vertical position of the body, which is the result of the social-labor practice of man, was the original reason for the development of such concepts as "above" and "below", "right" and "left", "front" and "back".

Psychophysiological studies have shown that the position of the body relative to the direction of the force of gravity, as well as the spatial relationships of the objects surrounding a man, are exceptionally significant in the general dynamics of spatial vision. /32 These studies confirmed Ukhtomskiy's concept, according to which vision is determined by a complex chain of associations: vision-kinesthesia-vestibular sensations. The coordinates of a man's fields of vision, the interactions of the monocular systems (i.e., both eyes), etc., are linked with this chain of visual-vestibular-kinesthetic reflexes.

As we have already mentioned, the acoustic organ also takes part in the analysis of spatial aspects. However, human potential in the field of direct acoustical perception of space is limited, and restricted mainly to a localization of sound. Its basis is the binaural effect, which involves a sequential perception of the sound acting on each ear. The olfactory analyzer has even less possibilities for localizing the source of an odor.

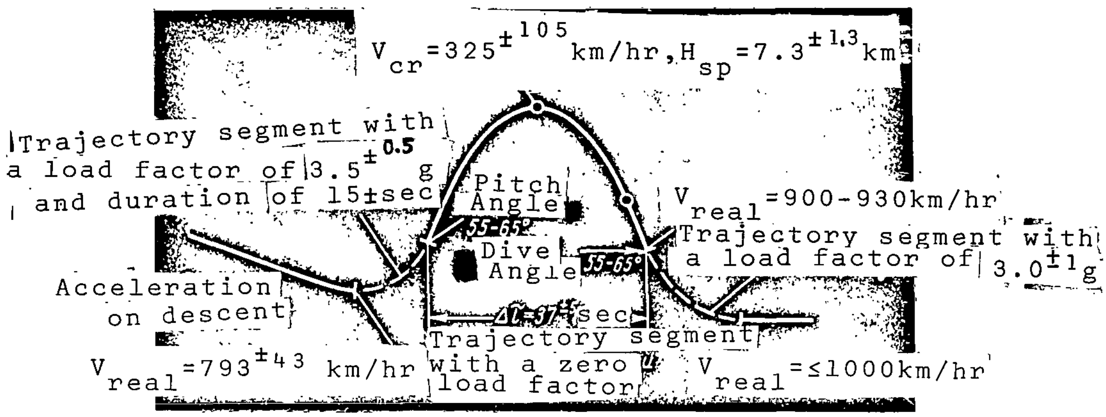
Thus, the orientation of a human being in space is achieved with the aid of a number of analyzers and those structures of the cerebral cortex which synthesize their activity into a single process of reflection of spatial aspects. Each of the analyzers reflects some one of the aspects of that complicated and complex stimulus which we perceive as a whole in the form of the spatial characteristics of the world surrounding us. The combined activity of several analyzers, forming a so-called functional system, acquires a new and higher quality, since it allows converting reflection of single aspects or properties of spatial relationships into a reflection of their combination. It also allows a man to respond to a certain combined stimulus with an entire reaction (not the sum of single reactions), which is a more complete, and thus a more effective, form of an organism's behavior in his interaction with the external medium.

Psychosensory Reactions in the State of Weightlessness

K.E. Tsiolkovskiy once proposed the idea that, under the conditions of weightlessness, a man can have different illusions, and there can be disorders of his orientation in space. However, he considered that man can adapt even to these unusual conditions. "Nevertheless, these illusions should disappear in time, at least in the living quarters".

Since that time and until the beginning of space flight, there were many opinions circulated on what effect weightlessness could have on the condition of an organism and its psychic activity. Some foreign scientists even maintained that the psychological reactions of a person subjected to a loss of weight would be dangerous to his health, and that existence in the state of weightlessness was completely impossible. Therefore, the corresponding experiments were first conducted on animals placed in high-altitude rockets. Subsequently, experiments were also conducted with human beings, but again during flights on jet aircraft (not spacecraft) along

Kepler's ballistic curve, with a very brief period of dynamic weightlessness (from 20 to 60 sec). At the present, a great deal of scientific materials concerning the effect of such weightlessness on the psychophysiological functions of people has been accumulated in our country and abroad. In this respect, all the subjects who have participated in such experiments can be subdivided into three principal groups. /33



Physical Characteristic of a Typical Flight with a Reproduction of the Conditions of Weightlessness.

The first group includes those subjects who underwent a brief period of weightlessness without any significant worsening of their general condition, did not lose their working capacity during the flight, and only experienced a certain weakness or feeling of lightness as a result of the loss of weight. All the Soviet astronauts belong to this group. For an illustration, we will mention the record Yu. A. Gagarin made after his first flight, during which weightlessness was simulated on a two-man aircraft: "Before the 'wingovers', the flight was normal and regular. During the first 'wingover', I was pressed against the seat. Then the seat went out from under me, and my feet were lifted up from the floor. I looked at the panel: it showed weightlessness. A sensation of agreeable lightness. I tried to move my arms, my head. Everything was easy and free. I caught the pen floating in front of my face and the hose of the oxygen tank. I was oriented normally in space. I could see the sky, the ground, and beautiful cumulus clouds all the time".

The second group includes those subjects who experienced illusions of falling down during the period of weightlessness, as well as a sense of turning upside down, a turning of the head in an indefinite position, suspension below the head, etc. These phenomena were accompanied during the first 2-6 sec by unrest, a loss of orientation in space, and incorrect perception of the surrounding situation and the position of the body. In a number of cases, there was euphoria (laughing, a playful mood, forgetting the program of the experiment, etc.). Subsequent flights with reproduced weight- /34 lessness did not bring about acute sensations in this group of people. They became accustomed and adapted. For example, we will describe the results of the observations made by one of the authors (V.I. Lebedev), which he wrote down after his first flight in weightlessness on a specially equipped aircraft.

"Before the first 'wingover', I sat in the seat and fastened the belts. By the sound of the engines and the vibration of the aircraft, I could tell that the aircraft was accelerating before the 'wingover'. Within a few seconds, I felt the overload and was pushed against the seat. At the beginning of weightlessness, I felt that I was falling into an abyss. This sensation lasted 1-2 sec according to my evaluations. My comrades were "floating" in front of my eyes. The parachute slowly raised itself up from under my seat, and was suspended in the air. The position of the people in the reference-less condition was unusual: one was head over heels, another somehow on his side, etc. They moved, turned somersaults, assumed unusual positions, pushed themselves off the floor, the ceiling and the walls, and rapidly floated in front of me. Everything seemed unusual and ridiculous. Knowing the sensations in weightlessness rather well theoretically, I expected that I would not tolerate it very well, but I found the opposite. It caused a sense of delight, which soon became euphoria. I put my thumb up to show my comrades that I felt very well. Then the weightlessness passed, and there was another overload. After the overload, the euphoria continued, until the beginning of the second period of weightlessness.

I was to 'float' in weightlessness during the second 'wingover'. I put on the protective helmet and lay down on the floor, covered with a thick layer of styrofoam. The overload began, and I began to be pressed against the styrofoam. The state of weightlessness began suddenly, before I had collected my senses, and I felt that I was flying to the top, and then in an indefinite direction. I felt complete disorientation in space. Then I began to recognize the situation somehow. I saw the floor and the walls. It seemed that the latter were moving away very rapidly. The illusion reminded me of the same sensation when you're looking through inverted binoculars. I glanced at the floor and saw that it was moving from below me, running away from me, together with the whole cabin, which was also decreasing in size. I tried to catch something at that time. Although the objects below me and at my sides seemed to be very close, I could not, in any way, reach them with my hands, which caused a feeling of extreme emotional agitation. Then, finding myself in the tail of the aircraft, I caught onto some object and stabilized by position in space". There was complete adaptation during subsequent flights.

Some of the subjects of this group felt disorders of their "body structure" as well as disorientation in space. For an illustration, we will cite the reports of the self-observations of one of the pilots who maneuvered an aircraft in weightlessness for the

Astronaut V. M. Komarov in the State of Weightlessness. /35

first time: "Within 8-10 seconds after the onset of weightlessness, I felt that my head was beginning to swell and increase in size. On the thirtieth second, I had the impression that my body was slowly revolving in an indefinite position. After another 15 seconds, I began to lose spatial orientation, and therefore I took the aircraft out of the parabolic regime". /36

This group also includes those who felt a sense of so-called mental estrangement, mental helplessness in the state of weightlessness. The subject M-v, an experienced glider-pilot, characterized his sensations in such a situation in the following way. "During the first seconds of the effect of weightlessness, I felt that the aircraft was turning over and flying in an inverted position, and I was suspended in the aircraft with my feet over my head. I looked through the porthole, saw the horizon of the Earth, and became mistakenly convinced that my sensation was correct. Within 5-10 seconds, the illusion disappeared.

During the illusion and after its disappearance, I felt that the entire period of weightlessness was disagreeable, difficult to characterize, a feeling of unnaturalness and helplessness I had not experienced before. It seemed to me that it was not only the situation in the aircraft which was changing; something within me also seemed to be changing. To avoid this disagreeable sensation, I tried to write in weightlessness, to reach my hands to several objects. I did all this without any particular difficulties. Nevertheless, this feeling of helplessness and instability did not pass over, and it caused a great deal of anguish."

The third group includes those subjects for whom spatial disorientation and illusions were more pronounced, continued during the entire period of weightlessness, and were sometimes combined with a rapid development of sea-sickness symptoms. For some of the representatives of this group, the illusions of falling down reached an extreme degree, and were accompanied by a sense of horror, involuntary screams, and a sharp increase of motor activity. In these cases, there is complete disorientation in space and a loss of con-

Astronaut A.A. Leonov Turns a Backward Somersault While Falling in the State of Weightlessness. /37

tact with the accompanying people. This mental reaction was described by F.D. Gorbov, O.N. Kuznetsov, and V.I. Lebedev as a so-called complex of "world destruction" sensations and many types of brain ailments. One of the appearances of this complex was described by A.S. Shmar'yan. Most of the third group felt that the attack began with an acute headache and dizziness. Not being able to hold onto something in time, the subject felt a sharp sensation of falling down. The objects revolving aroung him changed in size /38
and markings, "the compartments grew larger and then suddenly grew smaller, everything around was growing dark, objects were piling up on top of each other, everything was strange, unrecognizable, and alien". This occurred extremely rapidly - "faster than a tape going at high speed". The subject saw that large trees in the distance were being uprooted, "all the earth is like a seething cauldron left from the eruption of a volcano. Nature is being destroyed, people are dying, as during a world-wide catastrophe". During this time, Sh-v felt a strong fear, anguish and anxiety; he said good-by to life, and cried. This condition lasted 1-2 minutes for him.

These are the observations of L.A. Kitayev-Symka, who watched one subject experiencing a brief period of weightlessness. "During the flight, before weightlessness, he sat chatting easily with the doctor. During the first seconds of weightlessness, there was motor agitation, accompanied by reaching and grasping reactions, involuntary inarticulate cries, and a peculiar expression on his face (lifted eyebrows, dilated pupils, open mouth, lower jaw hanging). This reaction was observed during the entire period of weightlessness, which did not give the doctor (who was with the subject) any opportunity to contact him. After the effect of weightlessness, this reaction disappeared, but the subject was moderately agitated until the end of the flight. After the flight, he had the following to say about what had happened: 'I did not realize that we had approached the state of weightlessness. I suddenly felt a sensation of falling down, and it seemed that everything was falling to the ground, falling to pieces, dashing in different directions. I was seized by a feeling of horror, and I did not understand what was happening around me'. The subject remembered nothing about his reactions. In watching the movie film which had recorded his behavior in weightlessness, he was extremely surprised at what he saw".

As we can see, the complex of "world destruction" symptoms is very similar to the strong mental reactions found in certain people for whom the state of weightlessness causes disorientation in space accompanied by a sense of horror and a feeling of falling down. It is interesting to space psychologists that similar circumstances have been observed in neuro-psychotics when one of the symptoms of their illness consisted of a sense of loss in the weight of their own body. Thus, R.I. Meyerovich noticed that subject B-y "often showed a feeling of weightlessness - it seemed to her that she was moving in the air"; subject S-va mentioned that "at night, she sometimes wakes up with a feeling that she is suspended in the air". A.A. Megrabyan had similar observations (patient Sh. said: "I cannot feel myself or my body, as if I were floating in the air"; patient V. said that "sometimes her body becomes as light as down, weightless", which she feels is "like hanging in the air", etc.). The effect of certain psychopharmacological substances produces a similar reaction. For example, A.I. Sikorskiy noticed long before the first space flights that subjects with hashish-poisoning showed /39 a peculiar condition accompanied by a sensation of weightlessness and of being raised upwards.

It is natural that the following question should arise: With all these facts, can there be found some general rules which will aid in understanding the mechanisms for the development of psychic conditions with a disorder of the body structure and disorientation in space during weightlessness?

It has been explained that the appearance of the "world destruction" symptoms and many other psychosensory disorders is caused by a dysfunction, a mismatching of the work of the functional systems of the brain because of disease-produced damage to the central nervous system. One of the causes for this dysfunction could be altered and distorted information coming from the sense organs. A typical example of this is Ménière's disease, which was named after the French doctor who described it in 1861. It occurs in the following way. An outwardly very healthy man begins to feel periodic sensations of a "blow" on the head. As if "struck by lightning" he frequently falls to the ground so swiftly that he cannot catch onto anything. At the same time, he hears a noise in one ear, and feels dizzy. Some feel that they themselves are revolving and being thrown around; others feel that all the objects surrounding them are revolving (in a horizontal or vertical plane), that the objects are doubled and flashing, that the floor, ground, or bed is moving from under themselves, and that they are falling into an abyss. In these cases, some patients have a complete loss of orientation in space.

It was discovered that the ultimate cause of Ménière's disease was a periodic increase in the pressure of the fluid in the semicircular canals of the vestibular apparatus, which also caused the appearance of unusual and distorted information in the brain from this sense organ. This was confirmed by the experiments of Shtauder, who stimulated the vestibular apparatus on both sides in patients who experienced euphoria and ecstasy: after this experiment, the patients experienced dysphoria and sensations of a catastrophe and destruction.

Under the conditions of weightlessness, the brain begins to accept very altered and unusual information, since the mechanical forces caused by the Earth's gravity cease to affect the system of sense organs which perceive spatial relationships. The studies of Ye. M. Yuganov and other authors have shown that, as a result of a loss in weight of the otoliths, there are certain changes in the reciprocal relationships between the semicircular canals and the otolith apparatus of the vestibular analyzer. In this case, the weightlessness does not lead to a functional elimination of the otolith apparatus, but appears as an unusual minus-stimulus. This also causes a transfer of very different information to the brain.

There is also a substantial change during weightlessness in the information which comes to the brain from the skin receptors sensing pressure, the subcutaneous tissues, the baroreceptors of the cardio-vascular system, etc. Since the muscular strength necessary for supporting the body in a vertical position on the Earth is superfluous during an orbital flight, the flow of neural impulses from the osteomuscular apparatus is different. The recordings of the bioelectric activity of the antigravitational musculature also indicate this. In the studies by Ye. M. Yuganov, I.I. Kas'yan, and B.F. Asyamolov, it was found that the amplitude of the bio-electric potentials of the neck muscles, which is equal to 130-180 μV during a horizontal flight, decreases to a great extent (down to 40-50 μV) under the conditions of weightlessness and often even shows a bio-electric "silence". /40

The idea that weightlessness is a very strong and unusual stimulus has also been shown in electroencephalograph studies. The subjects who take part in flights with simulated weightlessness for the first time show a decrease in the amplitude of the bio-electric potentials of the cerebrum, accompanied by an increase of their frequency characteristics. In other words, the process of excitation predominates in the central nervous system.

All the circumstances enumerated above cause a disorder in the combined activity of the analyzers under the conditions of weightlessness. The result is that certain people have all possible types of illusions about the positon of their body in space, including complete disorientation and irregularities in correct perception of the external world and the "body structure". In those cases when the nervous system rapidly copes with such a functional disorder, and as a result, new interrelationships in the system of analyzers are rapidly established in correspondence with the changed situation, the subject can experience a feeling of agreeable lightness, of soaring; he will not lose his working capacity in such a case. Thus, for those with strong counterbalanced nerve processes, the unusual information can be accompanied by positive (sthenic) emotions; for those with a weak type of nervous activity, the unusual information can cause disorientation in space and subjective sensations and behaviorial reactions such as "world destruction" complexes.

As a rule, the reactions found in the astronauts during their flights in weightlessness correlated with their reactions under other stress situations. For example, sthenic emotions were noticed in all the astronauts during parachute jumps.

In the light of the problem concerning the effect of prolonged weightlessness on the perception of the body in space, it is of definite interest to mention the observations of G.S. Titov. During an orbital flight, he had disagreeable sensations which he characterized as a condition close to motion-sickness, and which were expressed by dizziness and nausea. When the astronaut turned his head sharply, the dizziness was intensified, and he had the illusion that objects were "floating around". Titov emphasized the fact that not only the /41 turns of the head, but also the flashes of objects ("movement of the Earth") caused the disagreeable sensations. However, he did not show signs of disorientation in space despite all this, which can be explained by the rather high indices of his higher nervous activity and his will power.

Nevertheless, we should mention that, even for those people with a strong nervous system, for whom vestibular-proprioceptive stimuli produced while effecting complicated turns are normal for the situation, there can arise serious disorders in orientation during the flight, accompanied by emotional-neurotic disruptions, in the cases of asthenia (exhaustion). F.D. Gorbov found this, for example, when he was observing the pilot N-v. The latter had done a great deal of flight-instructor work for several years, but had not shown increased fatigability. The characteristics of his flight work were found to be very good. During the subsequent 2-3 years, N-v began to feel increased fatigability, worked beyond his strength, and did not have normal rest periods. At times, during night flights, he experienced a violent bank towards the left, which he corrected "by will power", his "head pounding", concentrating on the indications of the instruments. He did not attach any significance to these phenomena.

Once, having made a climb during the night, N-v went into a cloudy zone. Immediately after this, he felt mistaken sensations of banking toward the left side. The flight regime did not change, and the sensation was smoothed over. The subject spoke about this while at a hospital, in a more or less restful condition. However, it was difficult for him to explain what happened after that; every time the story reached the point where he would discuss the sensations, N-v showed a pronounced reaction, cried, trembled, etc. Nevertheless, he finally explained that the remaining flight period was very difficult for him, that the mistaken sensation of banking actually did continue. During the landing process, N-v felt a vague and distressing sensation that his position and the position of the aircraft (inverted) had suddenly changed. This sensation did not disappear even when the airfield became completely visible. The subject underwent extreme physical tension, and a simultaneous feeling of a failure, falling down, horror. He completed the landing ("I don't remember how..."), and emerged "soaking wet" from the aircraft; his hands and feet were shaking, and he found it very difficult to walk.

In view of the prolonged reactive neurosis (diagnosis: persistent and pronounced manic-depressive condition with severe instability, weak heart, hypochondriacal fixations), it was decided that N-v was not fit for flight work.

Thus, a comparison of the clinical aspects of psychosensory disorders and disorders of perception observed during flights in weightlessness and during normal flights indicates that both types of disorders are very similar. The disorders in perceiving the /42 surrounding space and in self-perception caused by weightlessness in cases of insufficient adaptivity are phenomenologically similar to the psychosensory disorders in neuropsychotic patients. The cause of this is dissociation in the functional systems, although those with strong nervous systems usually do not reach a stage of complete disintegration. Moreover, the psychosensory disorders occurring during weightlessness have a number of phases. The first phase, dissociation of the activity of the analyzers, can be accompanied by insignificant and quickly-dismissed spatial illusions. The second phase is expressed by psychosensory reactions with disorientation in space and disorders of the body structure, but with correct interpretation of sensations. The third phase involves psychosensory disorders with distorted perception of the surrounding medium and delirious interpretations.

It is obvious that the phenomena described in this division must be studied in greater detail, considering the particular significance of a careful selection and training of astronauts, who must be prepared to experience weightlessness during a long-term space flight.

Orientation of a Human Being in Outer Space

K. E. Tsiolkovskiy was the first to draw attention to the problem of the spatial orientation of a human being outside the Earth. Based on general theoretical studies, he proposed the idea that the state of weightlessness during a space flight should cause a change in the perception of the surrounding space. In 1911, K.E. Tsiolkovskiy wrote: "There is actually no above and below in a rocket, because there is no relative gravity, and the body left without this force does not tend toward the wall of the rocket, but the subjective sensations of above and below nevertheless remain. We feel above and below, only their positions change with a shift in the direction of our body in space. On the side where our head is, we see above; where our feet are, we see below. Thus, if we turn with our head to our planet, it seems to be at a great height; if we turn with our beed (below) and look at our planet, it seems that it is submerging into an abyss, because it is far below. The picture is grandiose and dreadful, at first; then you become accustomed to it and actually do not lose your understanding of above and below" (1947, p. 71).

The following experiments were conducted in order to study the characteristics of spatial orientation in astronauts during a brief period of weightlessness reproduced on a two-man jet aircraft. The subject sat in the rear cabin, and fastened the seat-belts to the chair. During the flight segment in weightlessness, the pilot inclined the aircraft to the right and the left, to 60-65°. Before /43 the "wingover" (before the onset of weightlessness), the astronaut closed his eyes at the pilot's command, and informed the pilot (by radio) of his impressions concerning the spatial position of the aircraft and the nature of the turn being carried out. In such a situation, no subject showed spatial disorientation when he had visual control; when their eyes were closed, all the subjects had an illusory perception of the spatial relationships. None of the astronauts could determine the actual nature of the turn the aircraft was making when their eyes were closed. For example, V.M. Komarov described his sensations in the following way: "Spatial orientation was made difficult during the time the pilot was carrying out a "wingover" with banking; it seemed to me that we were flying upward vertically".

This disorientation can be explained by the fact that the information from the otolith apparatus arising during weightlessness is distorted; the subjects lose their concept about the position of their body in space relative to the plane of the Earth. However, they are well oriented in relation to the geometry of the cabin in the aircraft because of tactile and musculo-articular sensations.

A solution to the question of whether or not the range of sensitivity of the semicircular canals to accelerations changed under the conditions of weightlessness was of great practical interest to us. In selecting the methods for conducting corresponding investigations, we (K.L. Khilov, I.A. Kolosov, V.I. Lebedev and I.F. Chekirda) considered the limited space of the working area in the cabin of an aircraft and the limited time of the experiments. Our experiments were conducted in the following way. The subject sat in a Barany chair, inclined his head forward 30°, and closed his eyes (a thick band was placed around his head and over his eyes). Then the seat was rotated through 180° for 20 sec. If the subject did not notice the rotation, it was turned again, after an interval of 3-5 min, through 360° for 20 and 15 sec. The range of sensitivity to accelerations was determined only at the beginning of the movement; the sensations which the subjects experienced during the remaining period were not taken into account. The moment the feeling of rotation appeared, the subject reported it to the doctor, who noted the time by his stopwatch. In some cases, electronystagmograms were recorded. For the background, we used the data obtained for a horizontal flight. The rotation of the subject in weightlessness began within 5 sec after its action and at a rate by which we determined the range of sensitivity to acceleration of each subject under the conditions of a normal flight.

Eleven men, 23-45 years of age, with good flight endurance to weightlessness, took part in the experiments. Three men took part in one experiment; 5 were subjected to weightlessness twice during one flight, and 6 were subjected 2-6 times during 2-3 flights.

An analysis of the data obtained showed that the marginal sensitivity of the semicircular canals to angular accelerations changed under the conditions of dynamic weightlessness for all the subjects. This was expressed by an increase in the length of time necessary /44 for discovering such sensitivity to rotation. In other words, the excitability of the receptor formations of the semicircular canals decreased.

For subject V., the maximum length of time for the appearance of such a sensation during a horizontal flight was 12 sec, with a rate of rotation of one revolution per 20 sec; there were no signs of such a sensation at that time during weightlessness. For the remaining subjects, the time for the appearance of a feeling of rotation was 3-11 sec longer (on the average, 1.7 times longer) in comparison with the initial data. In this case, it was noted that the value of this increased period of time did not change during the course of one flight. On the other hand, during repeated flights there was a tendency for the length of time of rotation necessary for the appearance of the marginal sensitivity to weightlessness to decrease by 2-3 sec.

According to the theory of V.I. Voyachek and K.L. Khilov, with the normal action of the Earth's gravity the otoliths gradually show an activating effect on the sensory and vegetative reflexes from the semicircular canals. In our opinion, the "weight loss" of the otoliths in weightlessness leads to a decrease of such an effect. It also causes an increase in the margins of sensitivity of the horizontal semicircular canals to angular accelerations in the state of weightlessness.

In order to study the role of the semicircular canals in the spatial orientation of a human being in weightlessness, we (V.I. Lebedev, I.F. Chekirda) also conducted the following experiments. A rotating chair was placed in the flying laboratory. The subject sat in this chair with his eyes blindfolded. The researcher rotated the chair through a certain angle and at a constant rate (1 revolution per 5 sec). The task of the subject was to evaluate the angle of the turn without changing his body position (on the Earth, during a horizontal flight, and in weightlessness). The chair was rotated 5 sec after the onset of weightlessness (generally for 24-26 sec during each period of weightlessness).

In the first series of experiments, we determined the potentials and accuracy of orientation for turns from 0 to 360°. In the second series, the turns were made at the same angles, but we determined the accuracy of orientation during the fourth revolution. We succeeded in completing three measurements in the studies by the first variation for one period of weightlessness. In this case, the second and third measurements were made without turning the chair back to the initial position. There was one measurement for each period of weightlessness with the second variation. Half of the subjects were told the errors they made in their evaluations. Six men with flight experience in weightlessness and good endurance to it were examined in these studies.

The results of the experiments showed that the errors in determining the angle of the turn on the Earth and in a horizontal flight were identical. They consisted of ±10-20° in the first series of experiments and ±15-25° in the second series. The errors /45 in determining the angle at which the chair was turned increased under the conditions of weightlessness for all the subjects, without exception. In the first series of experiments, they were equal to -20-30° for a turn by 90°, and -35-70° for a turn by 180-360°. In the second series, the underestimation of the angle increased in some cases even to 270°.

The errors of the subjects to whom the data of the real angle by which the seat was turned were not reported did not decrease during repeated flights. For those subjects who obtained such data, the accuracy in determining the angle increased rather substantially from flight to flight.

What is the cause of all these phenomena? As we have already mentioned, the marginal sensitivity of the semicircular canals to angular accelerations increases in the state of weightlessness. Thus, when a subject is rotated to the same angle as that in a horizontal flight, the central nervous system obtains less stimulation from the corresponding receptors. As a result, the subject underestimates the angle of the turn.

V.I. Voyachek has found that the sensation of rotation depends, not only on the magnitude of the acceleration, but also on the length of time of its action (according to the formula $b \cdot t$, where b is the acceleration, and t is the time of the effect). In our experiments, the turning of the seat at a certain angle occurred with an identical acceleration during the beginning of the movement and the end; the time of the turn also was not changed. On the other hand, in relation to the increase of the margin of sensitivity of the semicircular canals during weightlessness, the subjects felt the beginning of the rotation somewhat later than during a horizontal flight. Thus, the times of the rotation were made shorter subjectively, and it seemed to the subjects that the turning of the seat occurred at a lesser angle than the real one. This intensified the effect from the decrease in the force of the stimuli in the brain from the receptors of the semicircular canals to an even greater degree.

This indicates that the perception of space and the perception of time are interrelated, and that both perceptions change under the unusual conditions of weightlessness. We will return to this idea later. Right now, we should mention the fact that not only the increase in the marginal sensitivity of the semicircular canals, but also the subjective increase in the rate of the passing of time (underestimation of the given time interval), play an important part in the underestimation of the angle by which the seat was turned. In the second series of experiments, the difference in the errors in comparison to the first averaged 5-10° for a horizontal flight; for weightlessness, it increased to 50-90°. This can be explained by the fact that the increase of the total time of rotation during the second series of experiments to 15-20 sec during weightlessness caused a substantial subjective underestimation of the actual time interval involved. Assuming that the turn lasted only 12 sec (instead of 15 sec, as was the actual case), the subject also underestimated the angle to which the seat was turned correspondingly. /46

Particularly interesting data on spatial orientation were obtained for orbital flights. At the moment of the transition from overloads to weightlessness, G.S. Titov had illusory concepts concerning the position of his body (head over heels). The instrument panel seemed to have moved and occupied the space over his head. The illusion disappeared within a short time. The American astronaut G. Cooper experienced similar false sensations. It seemed to him that the instrument case at his right hand had turned 90°. Other astronauts have also experienced an illusion of turning over with the onset of weightlessness. F.D. Gorbov related it to a continuation of the muscular reaction to support under new conditions. During the moment preceding weightlessness, the external forces (overloads) press the astronaut against the seat, and produce a muscular counter-support with the seat-back. If the tension of these muscles is not weakened during the following moment, there is a regular but false concept that the flight is continuing in an inverted position or upside-down. With a uniform muscular weakening, there is no such concept.

In the state of weightlessness, most of the astronauts form a psychological concept about "above" and "below" which was developed during their training on practice spacecraft. This concept is particularly important when the portholes are covered by screens. With this concept, they can orient themselves freely both with open and closed eyes. In the cabin of the spacecraft, the astronaut not only "sights" the instruments and objects surrounding him, but also obtains a large quantity of information by means of tactile sensitivity from the seat, the bases of the system, etc. In working with the control organs in the craft and other systems, substantial information flow goes to the brain from the receptors of the skin and the muscles. All this aids the higher regulating mechanisms of the brain in "handling" the distorted information from the otolith apparatus, and in a correct orientation of the medium surrounding the astronaut. If these possibilities are not realized, the illusions about the position of the body in space can remain for a long period of time. For example, illusory sensations of this type were observed by the astronauts B.B. Yegorov and K.P. Feoktistov during the course of an orbital flight. It seemed to one of them that he was in a half-bent position with his head below; to the other, it seemed that he was turned head over heels. The astronauts noted that the illusions occurred when their eyes were shut and open, and that there were no differences in the nature of the illusions in both cases. On the other hand, this condition was not distressing, and it did not seriously impede accomplishment of the planned operations.

For most of the astronauts, the psychological concept of "above" and "below" corresponded to the geometry of the cabin in the craft; when their eyes were open, their concepts were disordered only in the case when they saw the siderial sky "below" and the surface of our planet "above" through the porthole. This regularity was tested by one of the authors (V.I. Lebedev) in the following experiment. A pathway made of a special material was fixed on a wall of the aircraft-laboratory, on which the subjects walked in the state of weightlessness. In this case, the subjects rapidly developed the impression that this was not the wall but the ground, and that "below" was beneath their feet. On the other hand, as soon as they looked through the porthole of the aircraft and saw the Earth's surface parallel to their bodies, the impression disappeared. /47

In order to orient the craft, the astronaut must include it within the design of his body, and have a clear concept about his position, together with the position of the craft, in relation to the horizon of the Earth. In leaving one craft and transferring to another in outer space, as well as during docking operations, it is also necessary that the astronaut know how to orient himself in reference-less space. In order to study this, the following experiments were conducted during flights in weightlessness on the aircraft-laboratory.

The astronauts' task was the following: having begun to move in the "weightlessness basin", he was to close his eyes after a short time (5-10 sec) and, with his vision "turned off", he was to continue determining his position in space; then, opening his eyes, he was to compare his subjective spatial concepts in relation to the geometry of the "basin" to the actual situation. It was found that, during the first 2-5 sec of movement with closed eyes, the subjects, taking the rate of movement and the sensations of self-rotation into account, could still perceive what was occurring. It is true that there were gross errors at times. Subsequently, it was very difficult for them to determine the positions. Thus, A.G. Nikolayev reported about the corresponding experiment in this way: "After the beginning of the movement and after having closed my eyes during the first wingover, I evaluated my position in space in the state of weightlessness by memory. In this case, I felt that, in addition to the movement of my body along the basin, my body was rotating toward the right-hand side. According to my concepts, I should have been roughly in the middle of the basin, and have turned by 75-90°. When I opened my eyes, I saw that I was actually around the right-hand side of the aircraft, and that I had turned by 180°, i.e., my head was facing the ceiling.

During the second 'wingover', I did not open my eyes for roughly 10 sec. After 4-6 sec, I could not determine mentally my position in the basin. I had lost orientation. When I opened my eyes, I found that I was in the tail of the aircraft, 'suspended' with head over heels".

It was just as difficult to determine the spatial position of the body with closed eyes while rotating around the longitudinal axis during an orbital flight (when released from the seat-belts). It is interesting to mention that P.R. Popovich used the sound of the ventilator turning on as a reference point in space during these experiments. /48

We can see from all the above that, under the conditions of weightlessness, none of the indications of the sense organs except the visual senses, as a rule, can give reliable information for orientation in space outside the Earth. This is understandable in view of the fact that all the receptors known to us were developed, apparently, by the effect of terrestrial factors alone; only the eye developed as a result of a direct effect of space factors as well as terrestrial factors. S.I. Vavilov gave the human eye the graphic name of the "solar eye", in the sense that it was developed by the effect of many factors, but that an important factor was the adaptation of organisms to vitally important light rays coming from outer space.

Indeed, visual sensations and perceptions had become the basis of investigations of the Universe long before space flights were achieved.

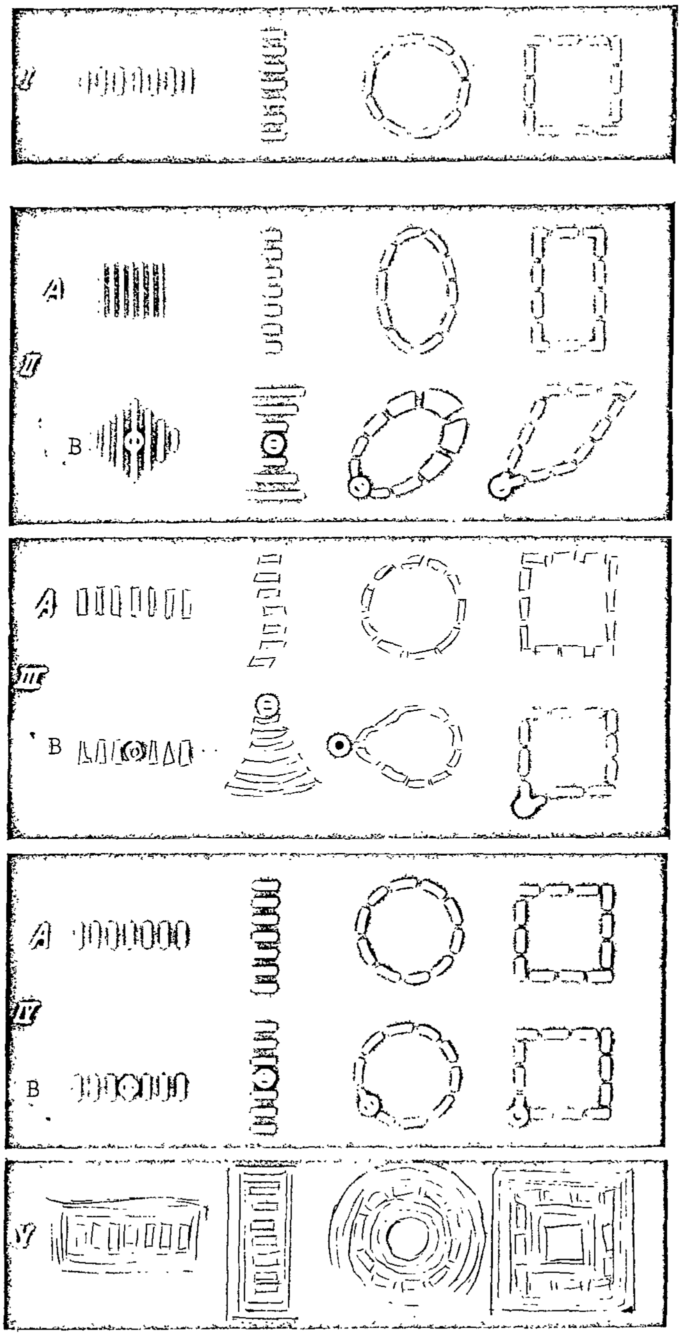
We mentioned before that the eye is very closely connected with the vestibular analyzer, and that the muscles of the oculomotor apparatus play a significant role in the process of vision. On the other hand, a brief period of weightlessness can affect both the vestibular analyzer and the muscular apparatus. Therefore, it is natural that the following question should arise: does this affect visual perceptions?

Studies which investigated this question were conducted by L.A. Kitayev-Smyk. During the investigations, he found that most of the subjects did not notice any changes in their visual perceptions under the conditions of weightlessness. However, some of the subjects had the following responses: "At the beginning of the weightlessness, I could not see anything"; "Everything was pale and blurred during the weightlessness"; "Everything moved downward"; "During the weightlessness, I saw only that object which I was looking at, and everything else disappeared".

In one series of experiments, the subjects were to look at figures (circle, square, etc.) drawn on a large sheet of white paper in the state of weightlessness. In another series, the subjects observed luminescent figures in complete darkness. In both cases, it seemed to many of the subjects that the images were magnified, blurred, paler, moving downward, and swinging. If the subject began to stare fixedly at some part of a figure, that part ceased to move and become blurred; it contracted down to its normal dimensions, but was very bright. The remaining parts of the image seemed to remain the same as before. As a result, the entire figure was distorted: a circle became an ellipse or pear-shaped, straight lines became curves. When the experiment was conducted in complete darkness, some of the subjects in weightlessness imagined that they saw a violet halo around the luminescent figures.

What is the mechanism of such illusions? At the present, we can answer this question only hypothetically, although it was discovered even during the nineteenth century /49 that perception of the markings on objects observed by such subjects is distorted during a stimulation of the semicircular canals of the vestibular analyzer.

Having studied the mechanism of the apparent increase of the figures, L.A. Kitayev-Smyk put forward the following hypothesis: "In weightlessness, the strength of the muscles bridging the eyes diminishes, and the eyes converge toward the nose as a result, there occurs a so-called convergence. On the other hand, the subject fixes his view on a certain object, as a rule (in this case, on the image of the geometrical figure).



Examples of Some Optical Illusions Formed Under the Conditions of Weightlessness. Perceptions of Figures: (I) In a Horizontal Flight; (II-V) Under the Conditions of Weightlessness: (A) Without Fixation of View; (B) With a Fixed View; (o) Point of View Fixation.

In order that the subject remain within the field of vision, the subject automatically strains the muscles which impede convergence of the eyes. In this case, the effect of feedback is seen immediately: the muscles signal the brain about this added strength. The brain processes the signal, as a result of which the subject has the following thought: the visible figure either expanded or moved further away (under normal conditions, such muscular tension is connected only with an expansion or recession of the object. On the other hand, the second condition (figure moving away to a great extent) would be possible only if the walls of the cabin in the aircraft suddenly move away. The subjects know very well that this is impossible. Therefore, their consciousness corrects the information obtained, and assumes that only the first position ('figure expanded') could be correct."

We should mention, however, that some people do have illusions of objects moving away from them under the conditions of weightlessness. For example, in one of his first flights along a ballistic Kepler curve , it seemed to pilot M-ko that the "basin" was moving away from him. The pilot Stellings noticed a spatial illusion that the control units of the aircraft moved away from him under the conditions of weightlessness. I wrote that "at first, I had some erroneous sensations in the state of weightlessness, so that I had to reach in order to touch various control instruments".

According to Kitayev-Smyk, disorders of vision occur during a brief period of weightlessness only at the beginning, as a rule, and they diminish by the end of the experiment. After several flights, the illusions disappear completely, and the subjects become adapted to the new situation.

The experiments conducted during orbital space flights are of particular interest. The doctor-astronaut B.B. Yegorov studied the visual analyzer with the aid of charts in order to determine the visual acuity, an adapto-reservometer which aided in determining the sensitivity of the eye to lights of different brightnessess, and a Herschel prism for studying the tonus of the eye muscles. According to the data obtained, the optical function did not break down during the course of the flight. The visual acuity, the light sensitivity of the eye, and the tonus of the eye muscles did not undergo substantial changes in comparison with the data established under terrestrial conditions.

The astronaut P.I. Belyayev and one of the authors (A.A. Leonov) conducted a scientific research study of the optical functions /50
according to the methods proposed by V. Popov and N. Boyko, on the "Voskhod-2" craft. The program of the study stipulated that the resolving power of the optical analyzer be examined. The visual acuity was tested with the aid of a collection of standard lined "Mir" ("World") charts inserted in the on-board notebook. It was necessary to stand at a distance of 300 m in order to look at them.

The resolving power of the astronauts' optical analyzer was determined preliminarily during laboratory studies, as well as during training on a practice spacecraft, where the program of the flight was repeated. The results obtained are compared with the data determined under the conditions of weightlessness during an orbital flight (5-6 orbits) in Table 1.

TABLE 1

	Visual Acuity		
	Under Laboratory Conditions (Five Measurements)	In a Training Spacecraft (2 Measurements)	In a Space Flight (2 Measurements
A.A. Leonov	1.7	1.4	1.64
P.I. Belyayev	1.7	-	1.34

We can see from the table that the resolving power of the optical analyzer changes insignificantly during a one-day space flight. The deterioration of I.I. Belyayev's visual acuity, in comparison with what was observed under laboratory conditions, can be explained by the nature of the illumination in the spacecraft.

The optical efficiency of the astronauts during the space flight was also determined according to the "Mir" charts. For this purpose, the subject found one element of the chart at which he could count the number of lines from a distance of 300 m. This voluntary selection of the element excluded the effect of the visual acuity on the result of the experiment, since the astronaut worked with an abnormal value in each case, i.e, with a value which was higher than the quality he normally would have under usual conditions. The results of the experiments in the laboratory, on the training craft, and during the space flight are shown in Table 2.

As we can see from the table, the operative optical efficiency decreases substantially during a space flight. This can obviously be explained by the fact that, under the conditions of weightlessness, the coordination of the group of oculomotor muscles is deteriorated to a certain extent, according to Popov and Boyko, as is the total coordination of movements, which we will discuss later. In the new situation, their effort to change the point of fixation of their view becomes distorted, as a result of which the eye seems to "miss" the necessary point in space. An adjustment other than the one described is necessary. However, this is very difficult in the given case, because a new impulse follows within 0.01 sec; this /51 impulse occurs during the refracting phase, and it is passed over. In counting larger details, this phenomenon is not observed, since the frequency of the impulses decreases to a great extent with an increase of the resolving angle.

TABLE 2

	Conditions of Observation								
	In a Laboratory			In a Training Craft			In Flight		
	Reliability %	Time of Operation sec.	Visual Acuity	Reliability %	Time of Operation sec.	Visual Acuity	Reliability %	Time of Operation sec.	Visual Acuity
A.A.Leonov	100	36	0.95	88	60	1.1	75	90	1.2
P.I.Belyayev	100	43	1.17	--	--	---	80.8	--	1.06

Another task imposed on the astronauts during the flight was to study their perception of color within the craft, for which a special chart was constructed. There were six different color strips on the chart; they were arranged at the side of graduated black-to-white tapers. It is well known that all colors become close to black as their brightnesses diminish. Therefore, they can be compared according to the characteristic in question. Three basic colors were selected for the study (red, green, and blue), as well as three colors complementary to them (azure, purple, and yellow). The astronauts were to find that region of the black-to-white taper which would have an identical brightness for each color. The average amount of error for a single determination of the color brightness according to the characteristics of the chart was equal to 15-30%.

A comparison of the results of the control (or background) and flight studies carried out during daylingt allowed Popov and Boyko to find differential changes in the perception of colors. They found that the subjective brightness of the latter decreases significantly in the state of weightlessness. The average decrease for all the colors used was 26.1% for P.I. Belyayev and 25% for A.A. Leonov. The greatest discrepancies were found in determining the brightness of a purple and azure color; the errors were somewhat less for the red. For the remaining colors, the decrease did not exceed 10%. In no case were the brightnesses intensified.

The cause of the substantial decrease in the subjective brightness of individual colors under the conditions of weightlessness /52 is still unclear, and its discovery requires additional and more detailed studies. At the same time, this effect did not prevent Leonov from drawing sketches of several space landscapes, both during the flight and after it (by memory). We will describe some of these sketches at a later time.

On the whole, there is adaptation of the optical analyzer during the period of weightlessness. On the other hand, this statement refers only to perception inside the spacecraft. At the same time, it is no less important to determine whether or not depth perception of space objects outside the spacecraft is disordered.

We mentioned earlier that the magnitude of the image on the retina, the tension of the eye muscles, accommodation and convergence, and the non-identicity of the right-hand and left-hand images are the principal components of those processes which allow perceiving the recession, volume, size and shape of objects. On the other hand, studies have shown, for example, that the accommodation affects distances only to 25 m, while convergence involves distances up to 300-350 m. Beyond these limits, the perception of magnitude and recession is based on certain indirect signs: comparison with other objects whose dimensions are known, clearness of the contours, etc.

In outer space, there can develop a situation in which the astronaut cannot see the Earth, the stars, or other reference points. Such situations have been called "reference-less vision". In this case, the effectiveness of visual perceptions decreases, and there sometimes arise illusory sensations.

Physiological optics has established that, in reference-less vision, the eye is focused on objects which are relatively close (not looking at further sights). In relation to this, the subject seems to become myopic. Thus, there are significant disorders in evaluating distance, which can make the work of the astronaut more difficult in certain cases. This was the case, for example, during the flight of the American astronauts McDivitt and White on "Gemini 4". They did not have a radar device, and they attempted to solve the task of leading the carrier rocket to the second stage by visual determinations. However, McDivitt determined the distance to the goal as 120 m, while it was actually equal to 600 m. It was necessary to install special radar devices on the subsequent craft of this series; the devices measured the distance between the craft and the docking object, as well as their relative speeds.

There is another fact which is no less interesting. The American astronaut G. Cooper reported that he saw houses and other buildings in Tibet with his bare eye during an orbital flight. On the other hand, calculations have shown that the resolving power of the human eye does not allow distinguishing such objects from such a height. We (V.I. Lebedev and O.N. Kuznetsov) explained Cooper's report as the result of an illusion of recognition caused by the insufficient informativeness of the stimulus. In this situation, /53
a correct comprehension of a stimulus is connected with mobilization of the corresponding concepts known from experience. When this is not produced quickly, the senses deceive, and there is an illusion of recognition. This idea can be confirmed to an extent by the

following special experiment, even though the experiment treats another analyzer (auditory).

The subject S-yev was isolated in a sound-proof chamber. During the course of the experiment, various partial and muted sounds were transmitted into the chamber. In many cases, when S-yev knew what was happening outside (say, an electrophysiological recording, a special hearing of a magnetic tape made by the attending staff after the reports, etc.), he perceived the sound and discussions in the apparatus rather accurately. With circumstances which were situationally unclear to the subject, he made gross errors. Thus, S-yev evaluated the sense of a discussion inaccurately, did not recognize a voice, and perceived the noise of an operating electric motor as a magnetic tape recording of a certain song sung by Robertino Loretti. The subject was firmly convinced of the reality of his sensations.

The role of vision is extremely important for orientation when a man leaves a spacecraft and enters reference-less space. In this case, only the umbilical connects the astronaut to the craft, and this is used to some extent as a reference element, but in a reduced form. In this situation, all the tactile and muscular sensations occurring by touching individual details and reference areas in the cabin are eliminated. In open outer space, the neural impulses coming from the musculo-articular apparatus and the skin receptors do not allow development of the concepts concerning spatial relationships between the astronaut's body and the objects surrounding them; they only give information concerning the interrelationships between different parts of the body, i.e., concerning the "body structure", which still includes the G-suit and the umbilical. Thus, when leaving a spacecraft in outer space, the astronaut's psychological concepts concerning his position relative to the geometry of the cabin, based on the visual, tactile, and musculo-articular sensations, are "destroyed", and he must transfer to an orientation "based" only on visual perceptions.

These are A.A. Leonov's impressions when he emerged into reference-less outer space: "In opening up the outer lid of the lock on the 'Voskhod-2' spacecraft, the immense cosmos stood before my eyes in all its indescribable beauty. The Earth floated majestically before my eyes, and it seemed flat; only the slope at the edges reminded me that is was nevertheless round. Despite the rather dense lightfilter of the 'window' of my pressure helmet I could see clouds, the glassy surface of the Black Sea, the edge of the cause, the mountain ridge of the Caucasus, the Novorossiysk bay. After emergence from the lock and a light repulsion, I began to move away from the craft. The umbilical by which I was attached to the spacecraft, and by which I could contact the commander, extended out all its length. The small force during repulsion from the craft caused an insignificant angular shift of the latter. The spacecraft rushing over the Earth was lined by the rays of the Sun. I did not observe any sharp contrasts of light and shade, since

/54

Astronaut A.A. Leonov in Reference-Less Outer Space Outside the Capsule

/55

the parts of the craft in the shade were illuminated fairly well by the solar rays reflected from the Earth. Stately green forests, rivers and mountains floated past. The sensation was roughly the same as in an aircraft, when flying at a high altitude. On the other hand, because of the significant distance I could not find cities and details of the relief, and this produced an impression that I was floating over an immense colored map. /56

I was moving around the craft, flying at a cosmic velocity over the rotating Earth. I withdrew from the spacecraft on my back, with an angle of inclination of my body of 45° to the longitudinal axis of the lock; I approached the spacecraft with my head forward, with my hands extended to prevent the impact of my helmet on the craft (or 'spread' over the craft, as in a free fall over the ground during a parachute jump). During the movements, I oriented myself in space with the moving craft and the 'standing' Sun, which was above my head or behind my back...

During one of the withdrawals, there was a complex twisting around the transverse and longitudinal axis of my body as a result of the repulsion from the spacecraft. Non-flickering stars began to float in front of my eyes against the background of a dark-violet-to velvet-black bottomless sky. In some cases, only two stars at a time appeared within my field of vision. The view of the stars alternated with views of the Earth and the Sun. The Sun was very bright and seemed to be packed in the blackness of the sky. The angular velocity quickly decreased because of the torque of the umbilical. During the rotation, although the craft was not visible, my concept about its location was preserved all the time, and I did not observe disorientation. I could determine my position in space relative to the craft according to the stars, Sun, and Earth floating within my field of vision. The umbilical was also a good reference point when it was completely extended."

Thus, the experience of orbital flights and the exit of astronauts from spacecraft into reference-less space have shown that a human being can adapt to orientation in these very unusual conditions. In this case, the relationships between the sense organs are other than those on the Earth. Vision, tactile and musculo-articular sensations acquire particular significance, and signals from the otolith apparatus are less significant. This new functional system of analyzers is less stable in comparison to the natural system which has developed during the long period of evolution and /57
historical formation of the human organism.

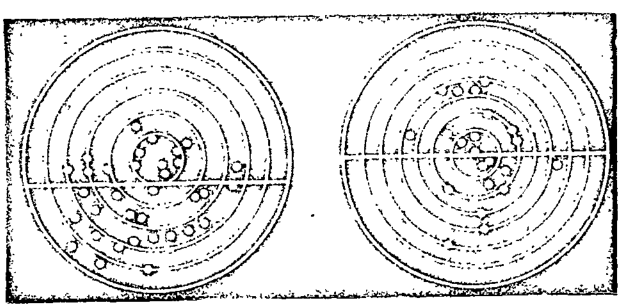
During future flights, when spacecraft and their crew will go beyond the Earth and move to other planets, and astronauts will be further and further removed from their craft in reference-less space with the aid of propellant devices, it is possible that there will be spatial illusions and disorientation. In relation to this, the problem of the orientation of a human being in outer space becomes even more important.

Coordination of Voluntary Movements in Outer Space

In orienting a spacecraft, in executing turns, etc., an astronaut must operate the levers, buttons, and toggler switches, not to mention many other motory tasks. Can a human being coordinate his movements accurately under the conditions of weightlessness? In searching for an answer to this question, experimental subjects were given a simple task. They were to drop the end of a pencil on a goal, the regular target for shooting from firearms. Under normal conditions, each subject "struck" the target, set an arm's-length away, without particular difficulties. In weightlessness, the accuracy by which this simple operation was executed decreased abruptly, particularly when the subjects closed their eyes. Subsequently, they became adapted, and the accuracy for hitting the target increased.

The mechanism for the disorder in the coordination of movements during the first flights with reproduced weightlessness was given the following explanation. On the Earth, when a man raises his arm or leg, the weight of the extremity and the inertia of its mass are overcome with the aid of muscle strength. Under the conditions of weightlessness, when the weight "disappears", only insignificant muscular strength is necessary to overcome the inertia of the extremity. However, in correspondence with the skills developed on the Earth, the neural centers send stronger impulses to the muscles at the beginning of the movement, as a result of which there is a "crossover". In particular, the arm of a man striking a target moves upward.

The coordination of movements during a brief period of weightlessness was studied with the aid of a special device - a coordinograph. The experiments were set up on the Earth, during a horizontal flight, and during a flight along Kepler's curve. These studies showed that the rate at which most of the astronauts executed motor acts slowed down during the period of weightlessness. For example, P.R. Popovich noted the following in his report: "In carrying out some exercise, it was very easy to hit the mark on the coordinograph when the movements were smooth. During sharp movements, there were misses, and the body changed its position". /58



Results of Dropping the Point of a Pencil on a Target Under the Conditions of Weightlessness (Right) and in a Horizontal Flight (Left).

It is extremely important that the astronauts preserve steady habits in reproducing certain muscular strains in order to operate the control instruments and other systems of the spacecraft. This also involves difficulties. In one of our experiments, the astronauts developed a steady skill of reproducing a given muscular force of 750 g (with an accuracy of ± 10 g). According to the reports of the subjects, they did not sense any difference in overcoming the corresponding resistance of the level of the dosimeter on the Earth and in weightlessness. On the other hand, the movie films showed that the accuracy of their work was substantially disordered during the "disappearance" of weight. During the first flight, the astronauts exceeded the force required by 250-1125 g. Only for V.F. Bykovskiy did the difference between the forces he produced on the Earth and in weightlessness equal only about 50 g. With an increase in the number of flights and reports to the astronauts of the corrections, the amplitude of the errors gradually decreased. As a rule, the subjects yielded the muscle force rather well by the second to fifth flight.

Due to the special training of astronauts on the Earth and in the "weightlessness basin", they can adapt quickly to the "disappearance" of weight during orbital flights. For example, Yu. A. Gagarin conversed by radio, made notes in the on-board diary, turned the toggler switches on and off, and conducted observations; during all these operations, he did not notice any disorders in the coordination of his movements, although he felt a certain discomfort because of the lack of the usual pressure of the back and seat of his chair on his body when executing some working operation. In general, the astronauts were able to do more and more work from flight to flight. They conducted observations of the stellar sky, auroras, /59 satellites, and the surface of the Earth, they measured the heights of stars over the visible horizon, tested the stability of a gas cavity in liquid and a water cavity in a gaseous medium, made photographs, carried out varied medicinal studies and other experiments, etc. In this case, the normal functional operations (turning on the toggler switches, working with the telegraph switches, orienting the craft, etc.) were simple and sufficiently coordinated, according to the reports of the astronauts. On the other hand, the establishment of new coordination relationships, active correction of forces in the process of a purposeful activity, the need for maintaining a certain position of the body relative to the surrounding devices and objects, etc. brought forth a feeling of fatigue rather quickly, as K.P. Feoktistov has mentioned.

An analysis of the objective data confirm the picture reported by the astronauts. Examinations of the movie films did not show any great changes in the sequence and coordination of large-amplitude movements. The manual orientations were in complete conformity with the flight data, and were carried out precisely according to the instructions. In this case, none of the astronauts exceeded the reserve of the operational unit. The astronauts recorded the magnitude of the pressure in the manual-control system, as well as the time of the beginning and end of the period when they piloted the craft manually. The telemetric data obtained also show that the astronauts' movements were sufficiently coordinated during the orbital flights.

But what is the case with more refined motor coordination? The handwriting analyses conducted by A.I. Mantsvetova, V.F. Orlova, V.Trubnikova, et al., can shed some light on this problem. They found that, when the astronauts wrote notes during orbital flights, their coordinations changed. This was found in varied tracings for the same letters and elements, unevenness of strokes, and unusual positions of the wrist while the astronauts were writing. These handwriting changes were characteristic of the case of an insufficient coordination between the large-scale movements of the fore-arm, upper arm, and entire wrist and the small-scale movements of the wrist and fingers. Moreover, there were breaks and twists in the straight lines, and oval-shaped and arch-shaped letters were angular and unordered in the notes the astronauts made in the on-board diary. These facts show that their accuracy in carrying out more refined movements decreased.

The greatest changes were noted during the beginning of an orbital flight. During the second to seventh orbits, the motory coordination improved and remained at the level of an average or more-than-average decrease. The changes in handwriting during the first orbits show the difficulties with which the refined movements /60
producing a smooth transition from bent to straight letters were coordinated. The greatest disorders were found in the arch-shaped movements, which require a smooth transition from one direction to another. Under normal conditions, these movements are accomplished by a combination of folding-straightening and approaching-withdrawing movements of the wrists and fingers; in weightlessness, the movements are simplified, and either the folding-straightening or the approaching-withdrawing movements predominate. On the other hand, the correct movements are recovered (adapt to the new conditions) as the flight continues. Moreover, there are signs in the astronauts' handwriting which indicate that new coordinatory relationships are developed. During the course of a flight, the tendency to simplify the handwriting movements is intensified, and the interaction of these movements as well as the form of the letters also become more simple. At the same time, the pressures of the pencil on the paper increases, as does the number of related movements. The punctuation marks, which are usually made separately, are joined by fine, hardly noticeable lines (the last letter in a word is connected to the following comma, etc.).

Thus, refined coordination of movements (handwriting, for example) changes substantially during an orbital flight. The value of the force component is different, and normal interactions between the central and peripheral divisions of the motor apparatus are disordered. A long period of weightlessness can be accompanied by a corresponding adaptation, expressed primarily by a simplification of movements. Such adaptation is noticed during the first day, and is intensified during the subsequent days of the space flight.

In relation to the training of astronauts to go out of a spacecraft in outer space, the movements of men in reference-less space were subjected to a detailed analysis. The studies were conducted on an aircraft-laboratory with a "weightlessness basin". It was found that those subjects who were in a reference-less state for the first time lost their ability to control their motor reactions. As soon as the period of weightlessness began, many subjects began instinctively to make "swimming" motions with their arms and legs. They seemed to try to support themselves in the air in the same way as people flounder around when they are in deep water for the first time. Subsequently, their movements became coordinated and "smooth". At the beginning, the subjects "flew" from one wall of the basin to the other because of the strong impulses; during the training, they learned how to preserve the stability of their body in space, or, as they say, to "soar".

In order to study the psychophysiological reactions of a human being in a reference-less state, the astronauts A.G. Nikolayev and P.R. Popovich were freed from the seat-belt system during an orbital flight. During this flight, they noticed involuntary move- /61
ments of the body toward the "ceiling". This effect can probably be explained by the rotation of the craft around the center of gravity. Although this rotation is very slow, it is sufficient for the arisal of an insignificant centrifugal force. Moreover, the fixation of the body in various positions did not involve great difficulties (according to the data of Nikolayev and Popovich), nor did revolutions of the body around its axis.

We must emphasize the fact that, although the astronauts were in a reference-less state, they were limited in space by the area of the aircraft-laboratory or the cabin of the craft in each case. The subjects could "float" up to a reference point and fix their position with the aid of this point, or push away from a wall and thus obtain an impulse for movement. As was reported by one of the astronauts, "it was necessary to push away from the ground with my hand in order to accomplish rotating movements. Subsequently, the rate of rotation depended on the position. In order to increase the rate of rotation, it was necessary to roll myself up into a ball; in order to decrease the rate, it was necessary to spread out." A.A. Leonov's task of going out of the spacecraft in outer space was basically new and much more difficult. The problems involved not only orientation but also coordination in an almost "purely" reference-less space which was not limited by the usual framework of the cabin.

We have already mentioned that future space dockings will have to be accomplished in open space. Any working operation, such as turning a screw or throwing some object, produces a movement of interaction of forces which turns an astronaut to the opposite direction. One of the authors (V.I. Lebedev) experienced this classic law of mechanics experimentally. A revolving Baraby chair was installed in the "basin" of the aircraft-laboratory. As we have already mentioned, this chair is used for studying the margins of sensitivity of the labyrinths, in particular. In order to acquire stability during such experiments, it is necessary to fix the feet in a special device beforehand. At one time in the experiments, the following happened (we will quote from the on-board diary): "During the first experiment to determine the margins of sensitivity of the labyrinths during the onset of weightlessness, my feet slipped out of the binding device, and I was suspended in the air, holding the arm of the chair with my right hand. Nevertheless, I attempted to conduct the experiment in this 'suspended' condition, and I began to rotate the chair. But I myself started to revolve around the chair (which I had not anticipated), while the latter moved only insignificantly".

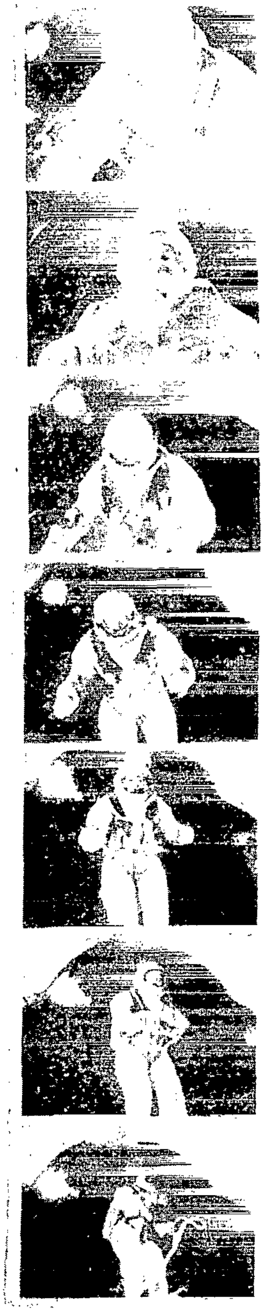
Before the first time a human being was to go out from a spacecraft in outer space, the astronaut was subjected to special training for his movements in reference-less space. The training was accomplished in the aircraft-laboratory, which included a model of the "Voskhod-2" craft with a full-scale transfer chamber. In this case, the accomplishment of the principal stage of the flight task (going outside and revolving) was conceived (and correspondingly developed) as a series of ordered operations. The astronaut was to /62 put on the satchel with the self-contained life-preservation system and fasten it to himself before moving into the transfer chamber. This was to be followed by a check of the equipment to be used for the emergence from the craft, and by equalization of the pressure in the transfer chamber and the cabin. Subsequently, the astronaut was to move into the transfer chamber, where he was to check the air-tightness of the pressure helmet and the G-suit, the position of the light filters, and the oxygen supply. After this, the commander of the craft would close the lid of the cabin-hatch, set the pressure, and open the lid of the exit-hatch. Then the astronaut would leave the craft, make the planned number of withdrawals from the transfer chamber and approaches to it, and, finally, return to the cabin. He was to carry out six operations in this working area (pilot's seat), eight operations in a non-fixed position during his movement around the cabin, and four operations in an unsupported position outside the spacecraft. The accomplishment of all these operations had the following results.

It was found that fixation in the working area guaranteed a rather high quality of the operations stipulated by the program. During the first two flights in weightlessness, there were changes in the coordination of movements (misses). During the subsequent flights, there were no such errors. The movements in a non-fixed position, inside the craft and the transfer chamber, were more difficult to accomplish. In this case, the astronaut did not have a reliable reference point. He only touched the side of the craft and the chamber. In carrying out these operations, many muscle groups of the body and its extremities were involved, as a result of which the changes in coordination became more pronounced. The quality of the operations performed depended greatly on the force of impact against a wall of the craft or chamber. With powerful impacts, the astronaut slipped through the pressure chamber rather rapidly, but there was a threat of colliding against the surrounding objects; with weak impacts, the operation was not always accomplished. The special outfit (G-suit) also imposed certain difficulties, particularly when it sustained the pressure necessary for an emergence into open space.

As for the approaches to the craft and, in particular, the withdrawals from it, the necessary skills were not developed immediately. The smoothness of movement and the length of time required were used as the criteria for the accomplishment of an exercise. According to Leonov's reports, "the very first withdrawal was also the best one, and was not repeated. After one 'wingover', I went out of the transfer chamber and back into it." This achievement can be explained to some degree by his repeated and attentive examinations of movie films in which the corresponding actions of two subjects were described, just as many "playbacks" in his mind about /63
all the necessary operations, and his personal experience of flights in weightlessness. Nevertheless, there were long periods of training after the first success before A.A. Leonov could repeat it. It required six attempts for him to develop skills in making a smooth emergence from the transfer chamber without a turn, and four attempts to approach the transfer chamber. At first, the movements were sharp, and the astronaut's body turned along the vertical as well as the horizontal axes. In carrying out the withdrawals during the first three flights, 19-20 sec were required; during the subsequent flights, 6-8 sec were required. In developing the approaches, the time required did not change at all. The very first approaches took a very short time (the astronauts rushed to complete this operation): this caused a decrease in the quality of their operation. The subjects did not approach the transfer chamber smoothly, and they made jerky motions and turns on the side or even on the back. In describing this period, A.A. Leonov wrote the following: "I tolerated the conditions of the flight very well. I did not feel any disagreeable sensations. My sensations were the same as what I had observed during previous flights in weightlessness. The G-suit limited my movements somewhat, and the field of vision was smaller because of the pressure helmet. The approaches to the transfer chamber were simple, since I pulled the umbilical and thereby produced a reference point and determined the direction of my movement. The approaches and withdrawals must be done smoothly. Apparently, any operations can be accomplished without significant disorders /64
in the coordination of movements in weightlessness with the presence of the most insignificant reference point."

It is interesting to compare the quality of his movements in the flying laboratory to those during the orbital flight.

A.A. Leonov completed five withdrawals and approaches in outer space, during which the very first withdrawal was made to a minimum



Kinogram of the Withdrawal Process from the Transfer Chamber into the "Weightlessness Basin" on the Aircraft, Accomplished by the Astronaut A.A. Leonov.

distance (1 m) for the sake of orientation under the new conditions. All the movements were accomplished in the same sequence as during the training. During the first withdrawals, his body turned to the side and forward; during the subsequent withdrawals, the exercises were accomplished correctly and reliably, which showed the adaptability of an organism to the unusual situation of reference-less space. Therefore, the coordination of movements, orientation and working capacity of a human being are not greatly disordered during a brief period of existence outside of a spacecraft in outer space.

It was explained in the experiments which were described in this section that an astronaut must settle himself relative to some reference point, or have a special instrument, in order to carry out working operations. In order to maneuver a craft, or to move from one craft to another, he must have special apparatus which produces a reaction force. It is well known that the American astronaut E. White was equipped with a "space pistol" which allowed him to maneuver himself with the aid of a jet-airstream during his walk in space.

Psychological Aspects of Orientation with Instruments in an Interplanetary Flight

We have already established that the eyes are the most effective sense organs for orientation in outer space. Due to vision, a human being can orient himself very well in a spacecraft and at short distances from it. However, the naked eye is inadequate for orientation in an interplanetary flight. Here, it is necessary to use instruments. This involves new and substantial changes in the activity of those psychophysiological systems which realize spatial orientation under terrestrial conditions.

During the long process of historical development, human beings have used natural reference points for orientation in space. With

With the advent of aviation, this became insufficient. The first attempts to fly in clouds and in fog (i.e., without a view of the horizon, the Sun, the stars and other references), guided only by sensations, frequently resulted in catastrophes. The period of "instrument-less flights" under complex meteorological conditions /65 soon changed into the period of introducing navigational instruments into aviation practice. It was then found that the pilots' sensations contradicted the indications of the instruments very frequently. In an overwhelming number of cases, the indications of the instruments were correct, while the sensations of the pilots were false. Such mistaken sensations were called illusions of the position of the pilot's body in space. Illusions of banks, rotation, soaring, inverted flight, etc., were the most frequent.

The physiological mechanisms of illusions during a blind flight are varied. It is generally accepted that the latter can be divided into types corresponding to the forms of perception (visual, vestibular, and others). Many illusions are connected with the simultaneous operation of two or three analyzers in their formation (visual-tactile, visual-vestibular illusions, etc.). The most detailed descriptions of the problem in question can be found in the studies of B.S. Alyakrinskiy, F.D. Gorbov, Ye. A. Derezyanko, and K.K. Platonov. We should emphasize the following concept described by K.K. Platonov: "The concepts of 'illusion in flight' and 'loss of orientation' are not one and the same. A loss of orientation with an illusion can be caused by non-criticality of a thought process, and not by disorders in perceptions. An illusion, sometimes even a very pronounced one, does not necessarily lead to a loss of orientation if the pilot treats it critically. In such situations, the pilot would say: 'It seemed to me that the craft was banking, but, looking at the instruments, I knew this was not so'. On the other hand, this is sufficient for a pilot to lose confidence in the indications of the instruments referred to, and he loses orientation" (1960, p. 166).

During flights on an aircraft, a pilot must orient himself constantly in relation to the line of the horizon; under the conditions of outer space, this need is eliminated. During orientation with the aid of a "globe" instrument, the astronaut projects his location onto some part of the surface of our planet; in this case, he does not have to worry about the position of his body and of the structures of the spacecraft relative to the direction of the flight and the line of the horizon. A solution to the problems of the latter type is necessary only when approaching some celestial body, landing on it, or executing certain turns (changing the inclination of the orbit, its altitude, etc.). In these cases, the astronauts (like the pilots) can have various illusions about the position of their body relative to the plane of the Earth and the direction of the flight.

From the psychological point of view, the principal characteristic of a flight with the aid of instruments is the transition from the normal (direct) orientation related to natural reference points to an orientation based on the instrument indications. Although the latter type of orientation also involves vision, the structure of the process in question is changed radically.

As B.S. Alyakrinskiy has stated, vision aids the pilot, not only in obtaining information from the instruments in the cabin, but also in achieving long-range orientation from the altitude of "a bird's-eye view" during a normal flight. In this case, the most important component of the system "man-flying apparatus-surrounding medium" is actually the "surrounding medium". The pilot must perceive the terrestrial reference points very clearly in order to establish the correct flight regime. In relation to this, it is possible that the pilot will allow great divergences in the course and altitude, since it is always feasible to correct the position of the aircraft at the necessary moment, because of visual orientation. The flight is constructed as a response to the incident stimuli, as it were, more perspectively. The point from which the pilot begins to produce the schematic design of orientation is outside the aircraft, but at the exact location of the aircraft. /66

The situation changes abruptly with a transition to piloting with the aid of instruments. In relation to this, the center of orientation is psychologically related to the cabin of the aircraft, the surroundings closest to the pilot, or even the pilot himself. As K.K. Platonov has emphasized, the "mental skill of indirect and dynamic orientation" is most important. Under these conditions, the astronaut or pilot determines his location in space, not as a result of direct impressions from the natural reference points to which he is accustomed, but with the aid of a system of technological devices which seem to be "wedged in" between the sense organs of the astronaut or pilot and reality. Moreover, the information the pilot obtains from the instruments is coded (enciphered), as a rule, and he has the new task of decoding (deciphering), which is usually unnecessary during a flight with the aid of vision alone. The principal difficulty in such deciphering is the problem of finding the concrete meaning of each signal. This meaning can be understood only by comparing one signal to other signals, by finding not so much the external dependence as the sense dependence between them.

In other words, when a pilot or astronaut obtains information during a blind flight, he must "read out" rapidly (i.e., determine correctly and decipher the characteristics of the instruments) and generalize the information into a completed concept of the position of the flying apparatus in space no less rapidly. Moreover, he must keep in mind the interrelationships between the indications of the instruments and the real situation. Naturally, the process of indirect orientation requires a much longer period of time than does direct orientation. However, this still is not all.

Achieving dynamic orientation in space, the pilot must remember the corresponding information obtained during the recent past (i.e., have a good operative memory) as well as foresee his location in the near future. It is just as important that the pilot or astronaut read the indications of the instruments and determine his spatial position at a certain tempo he establishes in relation to the speed of the craft and the nature of the surrounding medium. In general, the use of the indications of instruments involves substantial changes in the activity of those physiological systems which achieve spatial orientation. This is also seen to some extent in the activity of the entire central nervous system. According to I.P. Pavlov, the indications of the instruments are secondary-signal stimuli. Naturally, the phsyiological functions achieving spatial orientation during a blind flight include the structure of the second-signal system of the cerebral cortex to a much greater degree than during orientation by natural reference points. The new functional system formed to perceive spatial interrelationships is much more complex than the normal one. Since it is established only during the course of a few hours (not during the course of many centuries), its stability is comparatively low. Fatigue and the effect of disadvantageous factors on the human organism can quickly destroy it. /67

Everything we have mentioned in this division related to the orientation of a human being in space according to the indications of instruments during flights on airplanes and spacecraft. However, this type of activity will have its own psychological aspects under the conditions of an interplanetary voyage. We will discuss this further particularly because there have been no materials which treat this problem in the literature accessible to us.

During orbital flights, astronauts can conduct observations of the Earth's surface, including the regions below them directly through the portholes or through the "view" system, or in stepping out of the craft. In the case of orientation solely with the aid of instruments, people can also project their location on the Earth's surface by using a "globe" as a map. To put it briefly, an astronaut is always in a position to determine concrete regions of the Earth's surface during the process of a flight. Moreover, he can keep track of the trajectory by establishing more or less concrete reference points on the Earth. For instance, he can reason in this way: "Ten minutes ago, I was over North Africa. Now I am over the Black Sea, and I will be over the Urals within 10 minutes".

In contrast to an orbital flight, an interplanetary flight occurs, not between two relatively immobile points on the Earth, but between two celestial bodies moving in space at different velocities. A voyage to other planets will require not a day and not a week, but months and years (for example, about 5 months to Venus, and about 9 months to Mars, etc.). The astronauts not only will not be able to observe the Earth's surface and orient themselves according to individual regions of it, but also will generally determine the location of the craft according to stars selected as "references" in a completely different and unusual system of coordinates. Although interplanetary travelers will see constellations they knew on the Earth, they will have an unusual /68 view of the siderial sky which encompasses the bodies of the entire celestial sphere, and not a single northern or southern hemisphere. This also complicates spatial orientation. On the other hand, the celestial sphere will seem to be solidified, and there will be an illusion that the spacecraft is not moving, which is connected with the complete silence (if we do not consider the weak and uniform noise of the electronic devices, which is incomparable with the noise of working jet engines).

In such a situation, the importance of orientation with the aid of instruments increases to a very great degree, objectively and psychologically. The astronauts will be able to determine the flight trajectory (or check the corresponding information transmitted by radio from the Earth) only by measurements (with the aid of telescopes) of the angles of the "reference" celestial bodies and by feeding the information obtained into electronic computers, which will also determine the position of the spacecraft in the coordinate system selected. This position is expressed in a certain "abstract" point which is not connected graphically with any natural reference point. The calculated point to which the craft should be directed at a given time is not graphic, since the flight trajectory calculated in anticipation of the planet which is the goal of the voyage is at a completely different site at the moment of the calculations. We should add that it is definitely not as easy for the astronauts to correct the flight course as it is for pilots. Exceptional accuracy and timeliness in obtaining and analyzing the navigational information are necessary here. The smallest error could turn into an incorrectible accident and the death of the astronauts. On the other hand, keeping the craft precisely in the given course in space and time again depends on the faultless work of the special instruments and devices.

It follows from all we have said above that the astronauts must be fairly sure, psychologically, of the correctness of the instruments' indications (as pilots) as well as the reliability of the mathematical calculations and of the perception of the spatial and temporal aspects of space objects by theoretical (abstract) reasoning. The theoretical calculations will not always coincide with the sensory perceptions of a human being during the course of an interplanetary flight. So that this will not cause any unnecessary doubts, anxiety or fear on the part of the astronauts (which could lead to very ruinous afteraffects), it will be necessary to cultivate in the future interplanetary travlers a good knowledge of the mathematical apparatus of navigational instruments, and to /69
develop skills for various types of theoretical activity.

Certain Aspects of Training Astronauts for Orientation in Outer Space

We have already touched on a number of problems related to the preparation of a human being for tolerating the effect of weightlessness and for orientation in outer space. It is now expedient to discuss some of the problems of the corresponding training of the vestibular apparatus which we did not mention earlier.

Studies under terrestrial conditions have shown that the degree of excitability of the vestibular analyzer depends on optical stimuli and on the nature of the muscular contractions, primarily of the neck and the trunk. Thus, it increases when objects flash within the field of vision, when a man balances on an unsteady bearing, etc.

Therefore, the system of vestibular training must include the following: intensification of the resistance of the vestibular analyzer to stimuli under very different conditions; developing the system "vestibular-optical-motor analyzers" in order to avoid disorders in spatial orientation during altered gravitation and to reinforce the inhibiting effects on the vestibular functions, i.e., to develop the "pliability" of the functions of the central nervous system.

The training procedures which increase the stability of the vestibular analyzer can be subdivided into passive and active ones. The former include rotation of astronauts on different test-stands, rocking on swings, and stimulation of the vestibular apparatus by a pulsed current. The active preparations are accomplished during the hours of physical training, when the subjects exercise the vestibular analyzer as well as strengthen the muscular, cardiovascular, respirational, and other systems. They include rotation on a Rhine wheel, jumping on a trampoline, acrobatics, water dives, etc. During the period of his immediate preparations before a space flight, A.A. Leonov rode a bicycle for more than 1000 km, ran more than 250 km and skied the same distance, and carried out 103 training procedures for the vestibular analyzer by passive methods and 56 by active methods. He exercised daily on sports apparatus and accomplished many other types of physical preparation (sports games, etc.).

The training for "pliability" of the nerve processes is also a test of the neuro-psychic stability of astronauts in a soundproof chamber, when they must develop new mechanisms for adaptation to an altered situation in absolute silence. The failure of a subject to overcome a previously-developed stereotype mechanism /70 leads to a collapse of the higher nervous activity, i.e., to the development of neurotic conditions.

In this respect, the flights of the astronauts on jet aircraft acquire exceptionally great significance. In this case, the vestibular apparatus is being trained, and the astronauts also cultivate skills for orientation in space visually as well as with the aid of instruments. During these flights, the astronauts often have various spatial illusions which they supress by will power, teaching themselves to be oriented and to steer the aircraft solely according to the indications of the instruments.

In learning aircraft-piloting, the students of aviation schools practice on training machines which have dual controls. The first flights are always carried out in the presence of an experienced instructor who can interfere at any moment with the steering of the apparatus in the case of gross errors on the part of the student and thereby prevent disadvantageous afteraffects.

The training of astronauts is a completely different situation. The latter must acquire a knowledge of how to steer a craft without going into outer space preliminarily. Modern technology has aided greatly in solving this very complex problem; it aids in reproducing, in part, the conditions of a space flight on the Earth. The professional preparation of astronauts is conducted on a training spacecraft. It is a full-scale launchable apparatus, and it has an instructor's panel, a model calculating machine, apparatus for imitating the moving surface of the Earth and the siderial sky, and electrophysiological apparatus for recording psychophysiological functions. Before the astronaut goes into the cabin of the practice craft, he is equipped with detecting elements which determine the bio-electric currents of the brain, the heart contractions, etc., in order that the doctor-psychologist can determine the emotional condition of the subject. He then goes into the cabin and begins to prepare for the "space flight".

"Start!" The astronaut hears the noise of the jet engines which is reproduced with the aid of a magnetic recorder and powerful dynamic loudspeakers. Various signals flash on and off on the instrument panel, and the pointers of the instruments move and signal that the craft is entering orbit. These signals, which correspond to a real flight, are modeled by a calculating machine. Subsequently, the noise from the work of the engines stops: the craft has gone into the planned orbit. The electronic calculating device develops the model operation of a program which responds to the conditions of the orbital flight. The astronaut opens up the screens of the portholes and sees the siderial sky, the "Earth's movement", etc. All this is simulated by a special optical-electronic system of the type used in planetariums.

In order to develop skills for manual controls, the astronaut begins to orient the craft "in flight". The dynamics of the corresponding angular movements of the apparatus which should arise during actual activities are also modeled with the aid of the /71
electronic machine. The image of the Earth's surface and the siderial sky in the optical reference line shifts in relation to the steering actions of the astronaut on the craft. Naturally, the astronaut develops habits, not only of controlling the on-board systems, conducting scientific experiments, communicating by radio, writing notes in the on-board diary, etc., but also in correct programs for eating and resting.

During the "flight", the instructor and the doctor-psychologist carefully observe the certainty of the astronaut's actions. This is possible because all the on-board apparatus are duplicated on the observer's panel; the observer must evaluate the indications of the instruments. Moreover, the astronaut is observed through a television camera installed in the cabin of the craft. When the instructor desires, he can change the flight, produce various situations including emergencies, and see how the subject reacts to all this. At the same time, the doctor-psychologist observes the expression of the subject's face, the pulse frequency, the bioelectric potentials of the cerebrum, and other indications of the work of the astronaut's organism.

The characteristics of the skills ultimately developed during the training period are determined by the general picture, the rate, and the emotionality with which the exercises were carried out. The erroneous actions are determined and analyzed, as are the emotional reactions, activity, self-criticism, initiative, and psychomotor functions during the process of the exercises. An objective analysis of the characteristics of some astronaut's activity can then be compared with his behavior under every-day circumstances, during flights on airplanes, during parachute jumps, and in other types of training and testing.

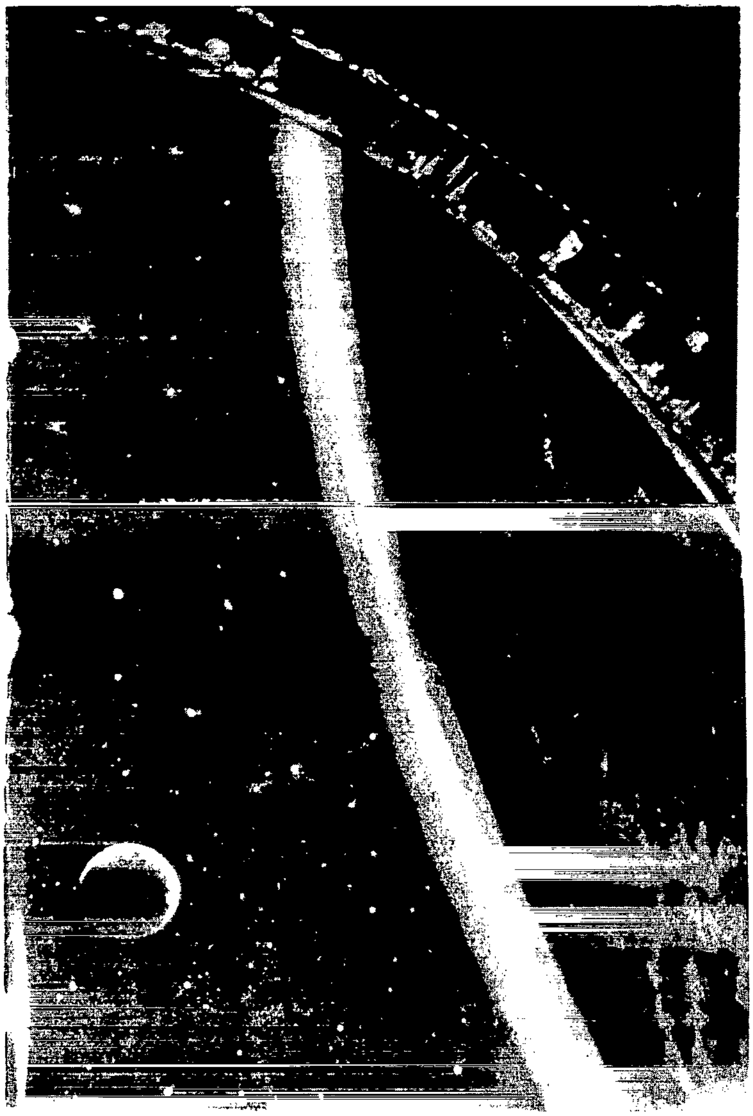
We must emphasize the fact that the characteristics of the formation of skills in different astronauts have clearly individualistic aspects. These reflect the typological, characterological, and professional natures of the individual. Nevertheless, the skills ultimately developed guarantee that the operations will be accomplished during a real space flight, despite the individual differences, and they depend directly on the rate at which they are developed and the number of errors during the training. On the other hand, it must be remembered that these characteristics are determined on the basis of orbital flights alone, and rather short flights, in fact. It is possible that the skills necessary for landing a craft on a celestial body by manual controls will be destroyed during the course of interplanetary travels. Therefore, it is possible that special functional training apparatus will be installed on interplanetary craft; these could aid the astronauts in preserving the skills developed on the Earth for steering the craft and solving the tasks imposed correctly.

Before drawing conclusions, we should discuss one more important problem: overcoming the tension when stepping out of the craft into /72 reference-less space. A.A. Leonov accomplished this task. K.E. Tsiolkovskiy foresaw these difficulties in his time. The hero of his science-fiction story entitled "Vne Zemli" ("Outside the Earth"), which was completed in 1916, says the following: "When they opened the outer door and I saw myself at the edge of the rocket, I went faint and made a convulsive motion, which pushed me off the rocket. It seemed that I had become accustomed to hanging without support between the walls of the cabin, and when I saw that there was a bottomless cavity below me, that there was no support anywhere around me, I felt faint again, and I came to only when the rope had unfolded its entire length, and I was a kilometer away from the rocket" (1960, p. 167). As we can see, the founder of astronautics knew that a walk outside of a spacecraft would involve the astronaut's overcoming the "fear of space". This is one reason why the solution to the problem of developing high emotional and will-power qualitits is such an important task in training astronauts. We can see how much these qualities have been developed in the following extract from Leonov's report: "As for the so-called psychological barrier which should seem an insurmountable obstacle to a man intending to encounter the bottomless chasm of outer space all alone, I not only did not feel any barrier, but also even forgot that it could exist. I never thought about it. Nevertheless, those 20 minutes under the conditions of outer space, including the 12 minutes outside the craft, were the 'high-point' of the flight of the 'Voskhod-2' craft. I understood this, and I did everything possible in order that not one second would be wasted". We would like to mention that the data of Leonov's self-observations correspond completely with the objective recording of his physiological functions, which determined the emotional condition of the astronaut. His pulse and respiration did not exceed the indices obtained during training periods on the aircraft and in the thermobarochamber. The timbre and intonation of his voice indicated (according to the results of a spectral analysis) positive, sthenic emotions.

This successful result was not a coincidence. Actually, numerous observations during the course of training parachutists-sportsmen have aided in drawing this conclusion: during a parachute jump, the skills of withdrawing from a flying apparatus, dropping and landing are developed, while the very important volitional qualities such as purposefulness, presence of mind, self-control, resoluteness and courage are cultivated. This developmental process was subjected to a special scientific analysis. It was found that the emotional-volitional reactions of a parachutist are the result of a complex combination of various psychophysiological mechanisms, and that /73 they depend on the amounts of time during which he trained and completed parachute jumps. The dynamics of these reactions are particularly clear in those making the first jump.

In general, a human being is capable of intentionally causing or halting some movement, transferring his attention from one object to another, and activating a number of psychic processes. On the other hand, these processes do not yield in the same way to conscious control and voluntary regulation. These processes include the emotions and reactions caused by the fear of a parachute jump for those making the first jump. In this case, the parachutist can arrest the internal expressions of anxiety only in part. The rhythm of his heart-beat and the frequency of respiration change, the arterial pressure of his blood increases, his muscular tension is strengthened, his metabolism processes change, etc.

During repeated jumps, the emotions of a parachutist lose their sharpness. The stability of his attention increases, and the tension decreases, i.e., there is normalization of the psychic functions.



A.A. Leonov's Picture, "Night on the Earth".

The parachutist gradually acquires the skills of guiding his body in space. The changes in the emotional conditions in dependence on the increase in the number of jumps can be illustrated clearly by the psychological observations of Yu. A. Gagarin on the days he made parachute jumps.

First day. Before the first jump, he showed agitation immediately after putting the parachute on. During this time, he was somewhat nervous and he spoke little, which was completely uncharacteristic of his personality. His gesticulations were poor and his voice was muffled. After completing the jump, he was elated but the tension was observed for another hour.

Second day. He was already less tense before the second jump. He joked a little, but the tension still showed up.

Fourth day. In carrying out this jump, he delayed opening up the parachute by 10 sec. In withdrawing from the aircraft, he bent inward and maintained a steady posture. He opened the parachute after 10.2 sec. His actions were correct during the parachuting. Before landing, he adjusted the belt system according to the wind. After the landing, he was in an elevated mood.

Sixth day. Before the drop, he was calm and good-humored. He joked a great deal and chatted with the doctors. After the jump, he was in an excellent mood. As always, he was noted for his humor.

Fourteenth day. He accomplished the final jump for the first stage of parachute training by opening up the parachute after a 50-second delay. He moved freely during the flight. He maintained a very good posture during the free fall. The parachute was opened up after 50.2 sec. After the jump, he was in an elevated mood.

Thus, Yu. A. Gagarin mastered himself very well, he showed /74 almost no internal agitation, and he showed himself a man with great will-power and self-control. During the entire training period, it was noticed that he combined self-mastery with a rapid cultivation of the necessary skills. A certain psychological tension was observed only during the first two jumps. High emotional-volitional qualities were also characteristic of the other astronauts, which can be explained by the careful medical and psychological selection as well as the experience of the subjects when operating jet-engine fighters. The parachute training in itself played and plays an important role in the future development of psychological stability under unusual and extreme situations. It aided greatly in A.A. Leonov's walk outside the spacecraft. Before that event, the astronaut had the title of a "parachutist-instructor", and he had completed 117 parachute jumps of various complexities. Due to this parachute training, he was able to eliminate the "psychological barrier" of reference-less outer space in full.

PERCEPTION OF TIME IN OUTER SPACE

Existence outside of time is the same supreme absurdity as existence outside of space.

F. Engels

When carrying out tasks imposed, accomplishing very different working operations, etc., an astronaut must calculate his actions in time very accurately. In addition to everything else, this is particularly important when he is steering a spacecraft, since he often encounters slowly-occurring inertial processes. We will explain this concept by means of an illustration. In orienting the craft, say toward some celestial body, the astronaut sends an impulse to one of the jet engines by turning the control stick. After this, the spacecraft begins to revolve around the center of mass by pitching, or in relation to its other axes. Before completing the turn to a lower angle, the astronaut turns off the working engine and turns on the other engine, which gives the craft the impetus to turn toward the opposite side. On the other hand, the apparatus continues the first turn by inertia. This stops only after a certain amount of time. In order that this turn might stop at a given point, the astronaut must determine the precise moment when he should turn on the second engine (and turn off the first). Otherwise , the orientation involves numerous trials and errors and a great expenditure of working strength, and the turn is accomplished later than what is required. /75

Accurate perception of time can be developed (and is constantly developed) under normal terrestrial conditions. However, the factors of weightlessness, prolonged isolation in small areas, limited mobility (hypodynamia), significant overloads, etc., affect a human organism during a space flight. The unusual and extreme factors cause high emotional-volitional tension on the part of the astronauts. All this somehow hinders (or can hinder) an adequate reflection of temporal as well as spatial relationships. /76
Therefore, scientists are confronted with the problem of finding ways, means and methods which can guarantee correct perception of time on the part of an astronaut under the conditions of a space flight.

Psychophysiological Mechanisms for Perceiving Time

According to modern theories, the human being does not have any special time analyzer. I.M. Sechenov was the first to show that the perception of time, as well as space, is accomplished by several "sensory apparatus". It is true that he first thought the auditory sense organ played the determinant role here. However, after subsequent studies, this scientist drew the conclusion that the perception of time intervals is admissible for any sense organ. In other words, a concept of time can be based on auditory, optical, tactile, and other sensations. On February 27, 1878, he wrote the following to I.I. Mechnikov about his work "Elementy mysli" (Elements of Thought"): "There are several points about the heart itself in it (in the work) (for example, thoughts about the role of the muscular sense in analyzing and measuring space and time)".[2]

I.M. Sechenov maintained that walking is the principal act which produces muscular sensations. He assumed that, "for various sensory aspects, the act of walking, the most usual phenomenon, includes elements for a human being to construct numbers for all their definite parts, as well as to determine lengths and small segments of time" (1952, p. 188). The principal unit of the periodic motion accomplished by walking is a step. It is both a spatial dimension and a dimension of time. Since a step involves a sound, it is accomplished not only by the muscles by also by the sense of hearing. Thus, there is simultaneity, association of two sensations, each of which confirms the other and gives a clear perception of the time interval. Moreover, according to Sechenov, hearing combined with muscular sensations aids to the greatest extent in analyzing the rate and rhythm, since the auditory apparatus itself and the functions inherent in it make it most capable of distinguishing the preceding and the following. Numerous facts concerning the perception of speech and music with their characteristic tempo aspects (pauses, rhythmic lines, etc.) have confirmed this position, as S.G. Hellerstein has shown.

The role of the act of walking in perceiving short pauses is /77
of particular interest. Sechenov maintained that the ability to sense their length "could not be developed solely by hearing". During the pause, the auditory apparatus is inactive. Therefore, the scientist connected the ability to evaluate short intervals of time with the primary movements of the body, mainly in the act of walking. According to Sechenov, walking at different rates is understood as a periodic series of short sounds, the pauses between which are filled by the muscular sense. He called walking the "school" where the hearing could learn how to evaluate various lengths of time for accelerating or retarding the footsteps.

In general,the act of walking is both a "periodic deferment of steps" in space and a "sound series with a constant duration of empty intervals". The muscular sense accompanying the step is "the gauge or fractional analyzer of space and time". At the same time, if the perception of the latter is least differentiated by kinesthetic (musculo-articular) sensitivity, then such differentiation is present to a sufficient degree in the other analyzers.

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2 Cited by D.G. El'kin (1962, p. 39).

For example, the optical receptor is primarily an organ which perceives space. In addition to this, it also has a definite role in the perception of time, since the eyes cannot function without certain movements (accommodation and convergence). Sechenov likened the optical axes of eyes following some object to two long feelers capable of expanding or contracting in relation to whether the observed object is withdrawing or approaching in space. These feelers seem to reproduce the entire path of the object and its rate of movement. That is why the muscular sensations arising during the work of the optical receptors allow evaluating not only the spatial aspects of the object, but also its temporal aspects. The special studies of D.G. El'kin and his students show this particularly clearly. It is true that time is perceived by the eye much worse than is space. As D. G. El'kin has justly stated, "this can be seen in the fact that the error in perceiving space in the process of optical sensitivity is much less than the error in evaluating duration" (1962, p. 136).

In a sense, the auditory organ is the opposite of the optical organ. It functions primarily with the perception of time intervals (in addition to sensing sound), although it can also aid in perceiving spatial relationships, as we have already mentioned. It is interesting that, according to El'kin, there is observed a certain motory "accompaniment" constructed in unison with the rhythm, rapidity, and duration of the stimuli during the auditory perception of time. This superstructure is provided for by the functioning of the mechanisms of reciprocal afferentation. Thus, the /78
sensation of rhythm is inseparable from the unique motory accompaniment; the accompaniment is a condition for adequate perception of time. It is not coincidental that perception of rhythm is much less accurate when the motory sphere of the cerebral cortex is damaged.

The tactile and interoceptive analyzers also take part in the perception of time. As A. R. Luriya has mentioned, this perception is generally accomplished with the aid of a number of analyzers joined into a system which acts as a single whole. The different nature of the time sensations corresponds to the different dynamic "composition" of the higher nervous system.

We know from experiments conducted in I.P. Pavlov's laboratory that animals can be oriented in time with an accuracy up to one second. On the other hand, this is incomparable to the orientation of a human being who can think in abstract terms. I.M. Sechenov has written that "we sense the duration of phenomena, since we can distinguish the beginning, middle, and end of very short time intervals. However, there is no man in this world who can distinguish the duration of phenomena which last a period shorter than one second directly by his senses. We think not only in minutes, but also in years and centuries. Again, this is veiled by the sensation" (1952, p. 403). This concept was maintained by V.I. Lenin who emphasized the following in writing a critique of Hegel's "Logic". "The whole point is that thought must encompass an entire 'representation' of its motion, and, for this reason the thought must be dialectic. Is the representation closer to reality than the thought? Yes and no. The representation cannot encompass the movements in their entirety (for example, movements at a rate of 300,000 km per second are not encompassed), while thought encompasses and should encompass them. The thought taken from the representation also reflects the reality; time is a form of existence of objective reality" (Vol. 29, p. 209).

Human abstract throught began with the advent and development of social modes of production, the collaborate transforming activity of people in relation to nature. In the same way, the perception of time on the part of a human being, just as all of his psychic activity, is developed and formed under the conditions of labor, or social-productive practice on the whole. As S. L. Rubinstein has shown, it would be incorrect to maintain that people only manifest themselves in their affairs, remaining the same after them as before. As a man realizes himself objectively and embodies himself in the products of his labor, he himself changes and develops. El'kin was correct when he wrote the following: "If we trace the development of orientation in time in a human being during the course of the social-historical process, we are struck by the fact /79 that it was formed and inseparably connected with the activities of labor. Actually, the entire course of historical development of human orientation in time is the long development of the labor activity of a human being, of his practice" (1962, p. 212).

We can determine the distinctinve characteristics of orientation in time in relation to different historical conditions and the levels of social progress. Thus, Lebbon found that primitive man lived primarily in the present; the past was short and indefinite. This can be explained by the very low level of development of productive forces at that time. The labor process, which was very primitive by its nature, was limited by a narrow time interval for primitive man; as a rule, he proceeded entirely in the present, never projecting his goals on the future, and never continuing what was begun in the past. Because of their imperfection, the stages of labor activity were only slightly differentiated. Thus, the differentiation of past, present and future was completely insufficient.

As productive forces progressed, man encountered the practical need for evaluating the duration of significant time intervals, for studying events of the remote past, and for predicting the future (river floods, disadvantageous moments for beginning to sow crops, etc.). Various auxiliary means and methods began to be constructed in order to accomplish such tasks. For example, the so-called points for reading time were introduced. On the other hand, even Aristotle knew that "the measurement of time is achieved by the measurement of movements, while movement is determined by time". Instruments for time measurements, which now have precision up to millionths of a second and more, have undergone a long historical development.At the present, various movements which are characterized by identical duration and periodicity are used as a measure of time for mankind, Since it is related to certain psychophysiological mechanisms and their systems, the perception of time can be destroyed, particularly when there are focal injuries to the cerebrum. Let us mention some characteristic examples.

Subject S., 32 years old. Malfunction of the thalamus opticus, expressed in a number of thalamic symptoms, was ascertained. It was observed that the subject showed malfunctions in perceiving time: she evaluated short time intervals incorrectly, and extended them substantially. The doctor asked S. to tell him when the end of one second had passed (he had marked the beginning of the second). Within 5-7 sec, the subject said that a minute had passed. After she had been shown the lengths of 5- and 10-sec intervals, she again took them as 1 minute, also. During the first weeks, the subject was disoriented in the present, could not name the present year, month, or date or determine the length of time she had been in the hospital,and took the morning as the evening.

In other cases, when there are injuries to the frontal lobes of the cerebral cortex, the subjects have no ability to plan actions /80 in time. For example, subject V. complained of headaches and a decrease of vision. The diagnosis was meningioma of the frontal cranial cavity with pressure on the frontal lobes, corpus straiatum, and interbrain. During the operation, a section of a frontal lobe was cut out. Within four days after the operation, the subject was disoriented in time: she said that it was 1928 (this occurred in 1938), and she determined the month and the season incorrectly.

Therefore, clinical materials also indicate that the basis for perception of time is found in the systematic activity of various regions of the brain, and not in the functioning of some particular "center". Since this systematic activity was formed as a result of the long evolutionary and historical development of mankind on the Earth, we are again confronted with the same problem we mentioned and clarified in the preceding chapter, in relation to space: will man be able to reflect time adequately under the unusual circumstances of existence in space? We will now examine this question in more detail.

The Effect of Emotions on the Perception of Time Relationships

During a space flight, astronauts are almost constantly affected by extreme and completely unusual factors, which causes emotional stress. Therefore, they often find situations when they must evaluate the passing moment by suppressing the regularly-occurring emotion of anxiety with their will power.

Precise experimental studies have shown that a man experiencing positive emotions underestimates time intervals, i.e., the subjective passing of time is accelerated for him; with negative emotional experiences, time intervals are overestimated, i.e., there is a subjective retardation of the passing of time. The following is an example of such a retardation described by B.S. Alyakrinskiy.

During a non-stop flight, the aircraft began to burn. There were two men and a pilot in the aircraft. This was the result of the situation: the pilot parachuted, and the remaining crew members died, although they also had parachutes at their disposal. During an investigation of the accident, it was found that the pilot (the commander of the craft) gave a signal to stop the aircraft before parachuting out. However, there was no response to his command, although he waited several minutes. Actually, the interval of time /81 between the moment the command was given and the moment he parachuted out was only several seconds. The overestimation of the length of time is very obvious here. Fractions of seconds were taken subjectively as minutes, which was also the cause of the death of the other two crew members.

Since an astronaut must evaluate time intervals precisely and treat the control units of the spacecraft in correspondence with this evaluation, we find a great deal of sense in discussing the psychophysiological nature of the subjective perception of time and its relationship with premature and delayed reactions.

M.F. Ponomarev studied the range in which students of one of the aviation schools opened fire during aerial shooting on ground targets. Forty-four percent of the students began to fire prematurely. Ponomarev maintained that the premature firing was connected with excessive overcautiousness and a fear of "being late" in completing the task (particularly during the first flights, for firing at a rapidly-approaching target). The reason for this was a suppression of the inhibiting process in the cerebral cortex by excitation. Ponomarev's conclusion has been confirmed by special experiments. The subjects of these experiments were asked to stop a stopwatch at a certain interval (reaction to a moving object, or as abbreviated, RMO). After the training period, the subjects of one series of experiments were given bromine, which intensified the inhibiting process, and those of the other series were given caffein, which intensified the stimulating process. It was found that the subjects of the first series showed premature reactions to a moving object, while those of the second series showed retarded reactions. Therefore, the prematureness, i.e., the overevaluation of time intervals because of emotional tension accompanied by fear or dread is caused by a disorder in the balance of the nerve processes in favor of inhibition. This concept corresponds with the opinions of I.P. Pavlov, who wrote the following: "That which is called fear, cowardice, and timidity in psychological terms, and which had its physiological substratum in an inhibiting condition of the hemispheres, represents various degrees of a passive-defensive reflex" (1951-1952, Vol. 4, p. 432).

Clinical observations of patients with manic-depressive psychosis also indicate the same concept. It seems that time passes extremely rapidly for such subjects when they are in a manic state, when the stimulating process predominates. "I do not have time to

stand up before it is time to lie down again", complained one patient. "When I sit down at the table, I find that it is already the end of dinner-time, and I must get up again. I am sometimes surprised that I have two or three minutes left to eat. I often refuse to believe it when people tell me that several hours have passed. Can time really fly that quickly? Why is it so? Why isn't it what it seems to me?" The opposite picture is observed /82
when subjects are in a depressive state, when the inhibiting processes prevail. After a period of depression which lasted about three months, one patient related the following: "It is as though everything were dead. The whole world has frozen. Melancholy. People walk very slowly. Everything is slipping away somewhere. Time has stopped. It has passed and has frozen. I have died or I never will die. I know that the second-hand is moving on your watch, but that is the only appearance of movement...You are ooming to me from another time".

As Ponomarev has emphasized, the fact that excitation causes retardation in actions, while inhibition causes premature reactions, is paradoxical and contradicts common sense. However, considering the nature of the principal nerve processes, it can be understood. Actually, inhibition, as the opposite of excitation, is always a cessation, limiting, or decrease of activity. Moreover, a consideration from the psychological point of view shows that a certain state of the cerebral cortex (excited or inhibited) could lead to a corresponding perception of activity which brings about a tendency to delay or accelerate a reaction.

Therefore, the relationship between a premature reaction and inhibition from any factors (including negative emotions) and the relationship between a delayed reaction and excitation (also for any reason), are achieved through a subjective retardation or acceleration of the passing of time in consciousness. For example, if some time interval seems shorter than it actually is to some man, then, when he is reproducing this interval, he actually makes a longer time interval. This type of relationship between the perception of time (reproduction of time) and the real time is seen clearly during parachute jumps. The methods of the corresponding experiments brought about the following.

The subjects of these experiments were trained to reproduce 10, 15, 20, 30 and 50-second intervals under ordinary conditions. As a rule, they counted in their minds in order to make this task easier. It was considered that the subjects had cultivated the skill of reproducing time when their errors did not exceed $\pm$ 0.5 sec. Subsequently they were asked to repeat this process during the free fall before opening up the parachute.

We should interject that, from the psychological point of view, there were three stages during the process of a free fall in a slow jump: the point of the beginning of the reading, which coincided with the moment the subject withdrew from the aircraft; the reading itself; the point of the end of the reading, which coincided with the moment the subject opened up the parachute. Both points, in themselves, represent the moments of time fixed by the subject. As for the reading, it is nothing but the reproduction of the given time interval. Because of their negative emotions, the beginning parachutists showed great difficulties in accomplishing this task. P.P. Polosukhin, a veteran parachutist, described this type of reaction in the following way: "One of my friends had accomplished more than a hundred jumps from airplanes and balloons, but he was afraid of executing a free fall for some reason. He tried several times to delay opening the parachute by 10 seconds, but he always opened the parachute the instant he began to fall. Then he decided to control himself, and he began to train himself by counting out seconds while he was on the ground. He paced around the entire day and muttered 'one...two...three...four' but he was the same way in the air that day as he had been. I was in the balloon-basket while he jumped out that day. I heard some inarticulate exclamation which seemed to mean that he had finished counting, and the parachute was opened immediately" (1958, p. 142). /83

The experiences of Yu. A. Gagarin during his first parachute jump are also interesting in this respect. "It was unusual. There was a large harness and the principal parachute behind me. There was also a harness in front of me, and the spare parachute. I couldn't sit, stand, or turn...I was wondering how I could manage everything there, in the air, with all that menagerie. It seemed to bind my arms and my legs...

I never liked to wait, especially when I knew that there was some difficulty or danger ahead. It was better to meet it face to face than to delay and procrastinate. Therefore, I was very glad, when after the first 'practice' jump, Dmitriy Pavlovich cried out:

'Gagarin! Get to the plane...'

It took my breath away. After all, this was my first flight to end with a jump in a parachute. I do not remember how we took off or how the 'Po-2' reached the planned altitude. I only saw that my instructor was giving me the signal: get out to the wing. Well, I somehow moved out of the cabin, stood at the edge, and held on to the sides of the cabin with both hands. It was awful to look at the ground: it was somewhere, far, far below. Terrible.

'Be a man, Yuriy!', my instructor cried out mischievously. 'Are you ready?'

'I'm ready', I answered.

'Well get going!'

I pushed off the rough edge of the aircraft, as I had been taught, and slid down, as in a precipice. I pulled on the ring, but the parachute did not open up. I wanted to scream but couldn't: I forgot to breathe in the air. I fumbled around to find the ring of the spare parachute. Where is it? Where? Suddenly there was a strong jerk. And silence. I was swaying smoothly in the sky below the white cupola of the principal parachute. Naturally, it had opened up on time: I had thought about the reserve parachute too early".

The overestimation of time intervals appeared very clearly during the first jumps with delays for opening up the parachute. For example, when astronaut N. made the seventh delayed jump, he opened up the parachute on the eighth second, instead of the fifteenth.

After repeated parachute jumps, the emotional stresses on the part of the astronauts did not disappear completely. Nevertheless, the fear of danger acquired the sthenic nature of excitation during /84 combat, which is connected with the activation of conscious activity. Such reactions to danger have a social nature. In relation to this, B.M. Teplov wrote the following: "Danger can be the direct cause of a sthenic type of emotional state which is shaded positively, i.e., connected with a unique enjoyment and heightened psychic activity" (1945). Actually, during the repeated parachute training periods, the astronauts noticed that the free fall occurred too rapidly, and that it was necessary to open up the parachute before they could enjoy the swift fall and gliding. In many cases, there were even observed delays in opening up the parachute, and the instructor was forced to emphasize the errors in evaluating time (which were not completely safe) during the reviews.

A.A. Leonov also experienced positive emotions of a sthenic nature, with a subjective acceleration of time, during his walk in outer space. "I was disappointed", he wrote in his report, "that the time assigned for working outside the craft flew by very quickly. The entire period I remained in outer space seemed to be only 1 or 2 minutes". It is true that the astronaut was not given the task of evaluating the time; therefore, he did not use any auxiliary instruments which could change his concept of time.

P.F. Lesgaft showed that, only with the aid of exercises can man learn how to "divide and compare impressions obtained and observe at the same time, thereby increasing his experience and the skill of analyzing his thoughts and actions" (1952, p. 108). During the parachute training period, the astronauts acquired the skills of coordinating movements and of reproducing (reading) given intervals of time accurately during the free fall. For example, when P.R. Popovich made the 12th jump with a delay of 20 sec before opening up the parachute, he pulled on the ring after 20.2 sec; when Yu. A. Gagarin made the last jump of the first stage of parachute training, with a 50-second delay, he opened the parachute after 50.2 sec.

Astronauts can develop particularly stable habits of accurate time perception under emotionally enjoyable situations during their training on high-speed aircraft.

The emotions of a pilot steering a modern high-speed aircraft are very dynamic and diversified. One of the causes for his emotional experiences during the flight is the altitude; these experiences can be positive or negative (often rather intensive). The fact is that the altitude always harbors a potential danger. This is realized very clearly during the landing or during emergency situations. On the other hand, in addition to the sensation of /85
danger, the altitude also brings about a particular, incomparable feeling which seems to give the pilot a new degree of freedom of movement allowable while piloting the aircraft. The effect of high speeds and accelerations also causes very strong emotions. Finally, the most important factor of these emotional experiences is the systematically-proceeding deficit of time.

As a rule, a human being can perceive the objects necessary for his labor on the Earth rather clearly and completely, he can realize the accumulating situations, solve problems, and accomplish some operation. During a high-speed flight, the time for all these types of labor is greatly reduced. In relation to this, B.S. Alyakrinskiy wrote the following: "It is generally characteristic of flight activity that a time deficit is reckoned in fractions of a second, seconds, and, only in rare cases, minutes, while a lack of time on the ground, if it does occur, is usually much longer. A good example of this is the traditional 'student's' lack of time considered as one day". Naturally, a pilot can solve problems arising during a high-speed flight correctly only when he has learned how to estimate time intervals accurately and how to "make the most of the time". In many cases, it is particularly necessary to perceive micro-intervals correctly. The professional activity of a pilot also aids in developing a good sense of time.

It is very important that an astronaut has this developed sense, because the steering of a spacecraft can often occur against the background of substantial emotional reactions. Thus, an inaccurate orientation achieved while turning on the retarding engine apparatus manually during a landing produces the threat that the spacecraft will go into an orbit which does not lead to the ground. Even a delay of a correct orientation can cause the danger of landing in disadvantageous regions (tundra, desert, mountains, etc.). More accurate reactions in time and space are required of the astronauts during a landing on a celestial body which has not atmosphere (for example, the Moon). Naturally, the first Moon-landings will also cause strong emotional experiences. That is why great significance is given to training astronauts for orientation in space and time against the background of various emotional conditions. P.I. Belyayev's successful landing by manual controls is an example of the advantageous results of such training. After this flight, the astronaut reported the following: "In relation to the fact that one of the control sticks for the automatic orientation did not work and the system did not begin to operate, I was assigned the task of landing with the aid of manual controls, i.e., of orienting the craft manually and turning on the deccelerating engine at the proper time.

The system of manual orientation worked faultlessly. There are no difficulties involved in orienting a spacecraft, particularly if the pilot has flight experience. On the other hand, piloting an airplane and orienting a spacecraft are obviously not the same. /86

Having oriented the craft at the proper time, I turned on the deccelerating engine system. After reducing the orbital speed in the dense layers of the atmosphere, the parachute was brought out, and, when I was very near the Earth, the 'soft landing' system began to operate".

Perception of Time during "Sensory Starvation"

Under the conditions of a space flight, an astronaut encounters, not only emotional tension, but also the phenomenon of the restriction of the flow of information (stimuli) from the external medium. This also causes a number of complex problems.

On the Earth, a man can usually glance at diversified pictures of nature and the creations of man one after another. All sorts of sounds act constantly on his organs of hearing and produce a sound background. The skin receptors sense changes in the temperature and movement of the air. The information about all these factors of the surrounding medium, transformed into nerve impulses, enter the brain. However, conscious recognition of this information is far from complete. In general, there is no calamity involved in this lack. Moreover, unconscious stimuli are very necessary for the normal functioning of the brain. They are the source of impulsion for the subcortical formations, which provide for the best perception of the activities surrounding the perceiver, thus feeding the working sections of the cerebral cortex the necessary amount of energy.

When there is even a minimum lack of stimuli, the functioning of the brain can be disordered in many different ways. For example, the famous Russian therapeutist S.P. Botkin (19th century) described a patient who was deprived of all types of sensitivity except for cutaneous senses, and that was only in the right hand. This patient was usually in a dreamy state, and she could be awakened only if something touched her hand. I. P. Pavlov examined a patient who, because of a trauma, had lost all senses except for one eye and one ear. As soon as he closed the eye and plugged the ear, this patient submerged into a deep sleep.

Having conducted numerous experiments on dogs in a "silence tower", Pavlov drew the conclusion that, for the normal functioning of the cerebral cortex, it was necessary that it be charged constantly by nerve impulses coming from the sense organs through the subcortical formations. The uniformity and monotony of impressions obtained when there is an insufficient quantity of external stimuli greatly reduces the energy level (tonus) of the cerebral cortex. In some cases, this can cause disorders in psychic functions.

Nevertheless, this situation can be rather typical for the conditions of a space flight. When the engines are turned off, the astronauts enter the "reign" of silence. When there are no radio transmissions, the cosmic silence is broken only by the weak and uniform noise of the working electronic devices. Therefore, it is no coincidence that the term "sensory starvation" has found usage in space psychology. This term characterizes an acute lack of stimuli. /87

It is true that scientists discussed the same phenomenon even before the first space flights, when the aerial "ceiling" increased to many thousand meters. Thus, foreign scientists studying the behavior of pilots on high-altitude one-man airplanes and balloons established that about 25-35% of the pilots felt a "sense of being torn away from the Earth" at altitudes of 10-25 thousand meters and more. Half of them responded with an agreeable sensation, "mainly a sense of triumph and a desire to continue the flight indefinitely". On the other hand, the other half reacted to it as to some horror. These pilots reported that "their senses were torn from their own bodies" during the high-altitude flights, and movement in space was accompanied by auditory and optical hallucinations. The sensation of being torn away from the Earth was explained as an abrupt decrease of the stimuli acting on the nervous system.

However, during the period when astronauts were being trained for the first space flights, science had not accumulated sufficient information about the effect of "sensory starvation" on an organism. Therefore, the problem of examining the working capacity of an astronaut when he has identical and monotonous impressions and insufficient stimuli from the outside began to acquire great importance in space psychology and medicine.

In one series of experiments, certain foreign researchers asked their subjects to go into special chambers. These subjects lay down on comfortable couches, glasses which scattered the light were put on their eyes, audiphones which did not permit even the sound of the subject's own speech were put on the ears, and covers which eliminated tactile perceptions were placed on the extremities. The subjects ate and performed physiological duties when necessary. In another series, a great restriction of the flow of external stimuli was achieved by submerging the subjects, who had special outfits, into a water reservoir. In this case, there was the possibility of isolation, not only from the sources of light and sound, but also from the flow of usual information connected with a reference on the ground or the surface of the cushion and tactile sensation.

These experiments showed that the reaction of the subjects was expressed mainly in what seemed, by outward appearances, to be "hunger". In a number of cases, this led to motory agitation. /88
During the first few hours, the subjects thought about the events of the preceding day, about themselves and about those close to

them. Subsequently, they began to experience a more or less pronounced feeling of "pleasure" from the experiment. This was soon replaced by a rapidly-intensifying need for stimuli from outside. In order to satisfy this desire, certain subjects banged on the walls of the chamber, twitched their muscles (in the water), made swimming movements, and struck one finger against another. When they suppressed the need for stimuli and remained in a calm condition, there seemed to be internal concentration. In this case, the subjects' sense of time was destroyed. They felt the lack of a clear concept, and they slept or dozed. Subsequently, they let their imaginations run wild, and hallucinations were developed. Most of the subjects refused to continue the experiment after 24-72 hours.

In the USSR, the experiments of restricting the amount of stimuli were conducted according to somewhat different methods. The subjects of these experiments were put in a soundproof chamber for several hours. They occupied themselves with imitated driving activities for a certain number of hours, and then were left to themselves for the remaining time. This situation corresponded to a greater extent to a real space flight. The studies conducted according to this method (under the leadership of F.D. Gorbov) showed that a healthy man with high volitional-morale qualities can preserve his working capacity for a long time in the sound-proof chamber without any psychic changes threatening his health. At the same time, the subjects did have sensory illusions. We (O.N. Kuznetsov and V.I. Lebedev) found these reactions in particular: illusions connected with an incorrect recognition of stimuli, the informative nature of which was insufficient for identification; the development of the feeling that there was another man in the sound-proof chamber; subjectively realized dreams; eidetic concepts; formation of invaluable ideas, and other phenomena (Kuznetsov, Lebedev, 1965a, 1966).

In addition to the numerous experiments investigating the working capacity and physiological and psychic functions of the subjects, we also conducted experiments investigating their capacity to reproduce given time intervals in a sound-proof chamber. The complex of tests was conducted in a strict sequence: thrice-repeated 20-second tests (beginning and end of the reading, pressing an arm and recording miograms), thrice-repeated 20-second tests with accomplishment of arithmetical operations at the same time, and thrice-repeated 20-second tests during occupational work, training to steer a spacecraft. Before these tests, the subjects developed their ability to reproduce a 20-second interval during parachute jumps for a long period of time (one year and longer). Subsequently, they were trained to reproduce the time interval under the control of a stop-watch for two days directly before their isolation in the /89
sound-proof chamber. Moreover, the subjects were also trained during the course of the experiment with the aid of the second-hand on the clocks inside the sound-proof chamber.

An analysis of the results obtained showed that their ability to reproduce the given time interval (20 sec) underwent definite changes while they were in isolation. These changes (although they were insignificant) appeared even during the period of preparation for the experiment. During the first day of isolation in the sound-proof chamber, the subjects were divided into three groups. We put the subjects for whom there was an increase of the reproduced interval, i.e., subjective acceleration of the passing of time, into the first group (30% of those taking part in the experiments). For example, the first group included subject P-v, who evaluated an actual interval of 30.5 sec as 20 sec. The second group (15%) included those for whom there was a gradual shortening of the reproduced interval, i.e., a subjective retardation of the passing of time; the third group of subjects (55%) included those who alternately accelerated or slowed down (subjectively) the actual time interval.

Obviously, this distribution reflects the nature and magnitude of the effect of isolation on the neuro-psychic realms of the subjects. Moreover, there were found three definite periods of maximum tension accompanied by the greatest errors in estimating time intervals: the beginning, middle, and end of the experiment. Each of these periods lasted from 12 hours to 2 days. Psychologically, this periodicity of tension during the process of the experiment was connected with the adaptation of the individual subject to the new situation. The beginning period was characterized by an orienting reaction, a period for becoming accustomed to the conditions of solitude and the driving activities. It was eventually replaced by a stage of stable operations. In our opinion, the period of tension during the middle of the experiment was caused by the extended habit of dividing prolonged, monotonous, and forced activities into two parts, or definitely established periods. This was experienced subjectively as a distinct break in which the subject evaluated the first half of the experiment and attempted to imagine the final stage as being of the same duration. The duration and amplitude of the tension during the middle of the experiment varied for different people, but it was practically insignificant for active and balanced subjects. After this break, the subjects' operations again became stable. The tension during the concluding period was caused by anticipation of the end of the experiment and emotional expectation of a return to normal life. During this time, the subjects accomplished only the regulated operations, and they summed up their work, collected their materials, or went from one thing to another in a disorderly fashion during the remaining time.

The most substantial errors in estimating time intervals (over- /90
estimation or underestimation) were observed while the subjects were doing arithmetical operations or being trained to steer a spacecraft.

Evaluating Time Intervals in the State of Altered Gravitation

We have already mentioned that the information going to the brain from the sense organs is altered in the state of weightlessness. In relation to this, it is of great interest to study the problem of adequate perception of time in such a state. In order to explain this problem in relation to the conditions of a brief period of weightlessness, we (V.I. Lebedev, I.A. Kolosov, and I.F. Chekirda) developed a series of experiments.

In one series of experiments, the subjects who were put in the first group were given the task of estimating the time they were in the state of weightlessness. During this time, the subjects were to execute some kind of task (operate a coordinograph, determine a certain muscle strength, test the handwriting in certain notes, etc.). i.e., they could not count the time interval mentally. As a rule, the subjects underestimated the time for the effect of the weightlessness during the first flights. They took an interval of 25-40 sec as that of 15-20 sec.

In other words, there was a subjective speed-up of the passage of time. Almost all these subjects showed positive emotions, which often turned to very moderate euphoria. On the other hand, those subjects who experienced disagreeable sensations in weightlessness evaluated (subjectively) an interval of 20-25 sec as one minute or more. During his very first flight in weightlessness, one of the authors (V.I. Lebedev) felt that the 24-second period of the first "wingover" (when euphoria developed) passed instantaneously, while the same length of time for the second "wingover" (when he had spatial illusions and showed negatively shaded emotions seemed to last forever.

In another series of experiments, an astronaut was to reproduce a 20-second interval at the command of the experimenter. During the first flights in weightlessness, the subjects again showed a subjective speed-up of the passage of time, but the errors were insignificant. The interval was reproduced as 21-23 sec. Undoubtedly, this showed their experience in reading time during parachute jumps (which preceded the flights in weightlessness). During the subsequent flights, after the experimenter had reported the astronauts' errors, they began to reproduce the necessary time interval very accurately. On the other hand, those subjects who tolerated the weightlessness insufficiently showed a subjective retardation of the passage of time. They reproduced a 20-second /91 interval in 16-19 sec. Even after the experimenter had corrected them, the skill of extimating a time interval precisely was developed very slowly, and these subjects did not always achieve the same accuracy they had attained earlier on the ground.

The doctor-experimenter I.F. Chekirda once observed a very interesting phenomenon. These are the corresponding notes from his self-observations: "During one of the first flights in weightlessness, I noted that one subject shortened the times for tilting his body and for the pauses between these actions during the Coriolis test. I mentioned this to him afterward. However, in calculating the recordings of the physiological functions, I found to my great surprise that the time in which he carried out this experiment corresponded to the program, and did not differ from similar experiments in a horizontal flight. I drew the conclusion that I, as an experimenter, estimated the duration of movements incorrectly in the state of weightlessness".

In all probability, the malfunctions in perceiving time during the first flights in weightlessness can be explained by the abrupt change in the information coming to the brain from the osteo-muscular apparatus, the otolith apparatus, and other organs. In any case, this problem must be studied in more experiments.

In the series of experiments described earlier in which a 20-second interval was reproduced during sensory starvation, emotional effects, and brief periods of weightlessness, some factors of a space flight were acting on the subjects. On the other hand, it is well know that these factors are combined in reality during a space flight. G.S. Titov also tested his ability to reproduce a 20-second time interval. Each test consisted of 20 measurements. After starting a stop-watch, the astronaut began to count 20 sec in his mind; when he estimated subjectively that 20 sec had passed, he stopped the stop-watch. The results were recorded in the on-board diary. The average arithmetical figures for these results, according to four tests conducted in a practice spacecraft (while "playing through" the flight tasks) and during an orbital flight (according to the data of V.T. Lebedeva), are given in Table 3.

TABLE 3

Site Where Tests Were Conducted	Times the Tests were Conducted			
	Morning	Daytime	Evening	Night
Training Spacecraft	20.8	20.2	20.0	21.0
Outer Space	20.3	20.2	20.1	20.1

The great accuracy with which astronauts have carried out working operations in outer space can also be proven by indirect data. For example, the astronauts have oriented spacecraft in the same time intervals as in practice craft, during the final training stages. The expenditure of working energy was also roughly equal in both cases. /92

Therefore, the astronauts could develop stable skills in estimating time intervals under the unusual conditions of a space flight (at least a brief space flight) during the training periods. On the other hand, during further conquests of outer space, the astronauts will encounter longer and longer periods of weightlessness, and what is even more significant, altered gravitation. For example, when landing on the Moon, an astronaut weighing 70 kg will weigh only 11.6 kg. Since his muscular strength will remain the same, the tempo of his movements will obviously be other than that developed on the Earth. But that is not all. K.E. Tsiolkovskiy wrote the following about the future impressions of space-travelers on the Moon: "The Russian man ran around, making huge leaps - 3 meters high and 12 meters long...The stones they threw up went 6 times as far as they would on the Earth. They came down very slowly, and it was very boring to wait" (1961, p. 211). He also wrote:"I feel that I am standing up particularly freely, as if I were in water up to my neck: my feet are hardly touching the ground...I cannot resist the temptation - I leap into the air,..It seemed to me that I went up rather slowly and came down just as slowly" (1961, pp. 7-8). In relation to all this, we are confronted with the following problem: Will astronauts really be able to coordinate their movements in altered gravitation during their very first steps as well as Tsiolkovskiy imagined? Will not this situation be reflected in their perception of time?

As for the first question, the foreign research studies conducted on special test stands found, for example, that a slow walk could be accomplished during an imitation of decreased ("lumar") gravitation without any particular difficulties. On the other hand, rapid movements lead to a loss of equilibrium. The subjects in these experiments fell down. At the same time, they acquired a capacity to perform exercises which only experienced gymnasts could accomplish on the Earth. To illustrate the sensations arising under such conditions, we will insert an excerpt from the recount of one of these subjects. "The first step. I am sure that I applied too much effort for it. I soar upward with surprising ease and, moving my feet helplessly, I come down several meters away from the starting point. But I am not where I guessed I would be. One more push and everything is repeated...I try to run, but I cannot. I push off abruptly and energetically with my feet and...I 'fall down'. I feel as though I had suddenly slipped on ice: the faster I try to move my feet, the more difficult it is to keep my balance...I try to move in short steps, slightly sideways. It is easier to keep /93 my balance this way. It seems strange, but the rate at which I am walking on the Moon hardly exceeds one half a kilometer per hour - 20 steps per minute. This is because, pushing off from the Moon's surface, I move more slowly than on the Earth...I try again to jump onto the 'lunar stone' (this was the subject's concept of a bench. Authors' note). I can keep my bearing with one foot. But only one. I tumble over the obstacle and stop a meter away from it. After soaring in the air for a while, I find myself in a very intricate posture".

Naturally, the movements of the subjects were limited by the training apparatus in the imitation of lunar gravitation. This distorts the picture observed. In all probability, a "purer" decreased force of gravity can be obtained in aircraft by executing specially planned turns. On the other hand, we can draw a preliminary conclusion on the basis of the experiments conducted, even though they were very incomplete. The conclusion is that the rates of movement people will achieve by walking will change substantially on the lunar surface (and under conditions which differ greatly from those of terrestrial gravitation).

In relation to the question about the effect of altered gravitation on the perception of time, it is necessary to mention the following. We have already described I.M. Sechenov's idea that hearing combined with muscular sensations are used to the greatest extent in analyzing the rate and rhythm of a walking process. The rate and rhythm of movements will change on the Moon. Moreover, the latter will not be accompanied by sound phenomena, because of the vacuum (if we do not consider the sounds inside the pressure-suit of the Moon-traveler). All this, combined with many other factors, will probably lead to a change in the perception of time.

Perception of Time and the Magnetic Fields

Soviet Moon probes have found that the Moon does not have a significant magnetic field. Therefore, it would be unsuitable to orient lunar travelers according to the magnetic compasses to which we are so accustomed on the Earth. The astronauts will be required to determine their location according to various celestial bodies, or according to the indications of instruments which act on different principles. But this is not the principal problem. What is most important is that the magnetic field will cease to affect a man on the Moon, as well as on other planets and during an interplanetary flight, in a number of cases.

We all know that all living beings populating the Earth were developed and constantly affected by the geomagnetic field. Now we have a problem: will not this lack of a magnetic field affect the physiological and psychological functions of a human being, particularly his time perception? In order to answer this question, we will attempt to treat various theories of magnetobiology, even though this field is now only in a beginning stage. /94

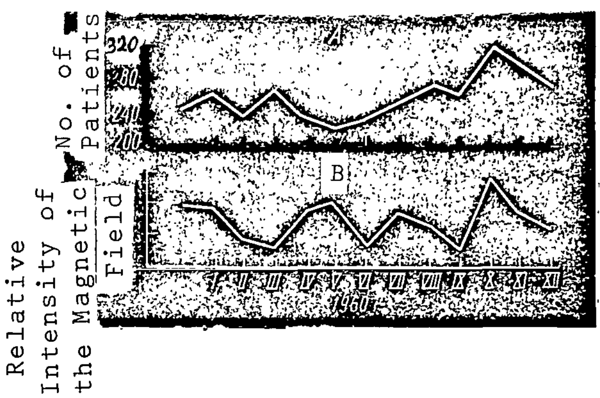
German psychoneurologists found a relatively long time ago that the number of neuropsychotic patients increases during the periods of magnetic storms, when the intensity of the geomagnetic field begins to change rapidly. These data were obtained by an investigation of forty thousand case histories for five years (1930-1935). The same type of studies were conducted in the sixties in the USA, by a statistical analysis of twenty-nine thousand cases of neuropsychotic illnesses found during a four-year period. These materials were compared with weekly information about the intensity of the Earth's magnetic field. The studies confirmed the idea that the number of neuropsychotic patients and their fatality rate increase during the periods of magnetic storms.

In relation to this, the studies of V. Desyatov are also of great interest. This scientist analyzed the dynamics of suicides and automobile fatalities from 1958 to 1964 in connection with powerful eruptions on the Sun. The latter cause very stong magnetic storms on the Earth. Desyatov reported the following: "It seems that people with weak nervous systems and chronic alcoholics feel extremely depressed after eruptions on the Sun. As a result, the number of suicides increases by a factor of 4-5 on the second day after the solar eruptions, in comparison to that for quiet solar days. The idea of suicide, which seems insignificant on the days of the quiet Sun, becomes an overwhelming desire on the days after solar eruptions.

The number of automobile fatalities also increases on the second day after solar flares - almost by a factor of 4, in comparison to the days of the quiet Sun".

Observations of this type are becoming more and more important to scientists. There is now a rather substantial amount of information in scientific literature about the effect of electromagnetic waves of different lengths on the central nervous system of animals and human beings, as well as on intracellular protein molecules. For example, American researchers have subjected subjects to centimeter-length radio waves. During irradiation on the temporal part of the head, the subjects began to hear sounds which they thought arose in the back of their heads. During irradiation of a monkey with waves of one meter, there was noticed an abrupt change in its behavior: at first the animal pricked up its ears, then it went to sleep, but it awoke in a very short time in an agitated state. Ants which were put in a zone of radio waves of three centimeters began to orient their feelers parallel to the magnetic lines of force.

The numerous experiments with different animals have shown convincingly that the electromagnetic fields affect the nervous system and cause various physiological and behaviorial reactions. These experiments also showed that the reactions often do not depend to a great extent on the energy characteristics of the acting field.



Graph for the Admittance of Neuropsychotics in a Hospital for the Year 1960 (A), and Graph for the Change in the Intensity of the Geomagnetic Field During the Same Year (B).

How does the electromagnetic field affect the psychophysiological reactions of animals and human beings, particularly their perception of time? An answer to this question can be given only hypothetically at this time. /95

Having studied the temporal aspects of the physiological mechanism for a conditioned reflex, I.P. Pavlov wrote the following: "How can we understand time, in physiological terms, as a quality of a conditioned reflex? Naturally, we still cannot give a precise and definite answer to this question. But we can come close, in a certain sense. How do we mark time in general? We do it with the aid of various cyclic phenomena: the rising and setting of the Sun, the movements of the hands on the face of a clock, etc. Actually, we also have many of these cyclic phenomena in our bodies. The brain obtains stimuli, becomes fatigued, and then recuperates in one day. The digestive canal is periodically filled with food and then releases it, etc. Since every condition of an organ can be reflected in the brain, this is the basis on which one moment of time can be distinguished from another. Let us take short time intervals. When a stimulus has just been introduced, it is felt very sharply. When we enter a room which has some odor, we sense it very strongly at first, and then less and less. The condition of the nerve cell affected by the stimulus undergoes a number of changes. It is the same in the opposite case. When the stimulus is stopped, this is sensed very sharply, and then more and more weakly and, finally, we do not even notice it. This means that we are again confronted with many different conditions of the nervous /96 system. From this point of view, we can understand both the cases of reflexes to an interruption of a stimulus and the following reflexes in the same way as the cases of a reflex to time. In the experiment I conducted, the animal ate periodically, and a number of organs aided in performing this activity, i.e., there was a number of definite sequential changes. All this was recognized in the brain, and the precise moment for these changes yielded to a conditioned reflex" (1951-1952, p. 57).

Therefore, the cyclic phenomena in various parts of an organism can appear as biological clocks which allow the animals to "measure off" certain intervals of time. Moreover, isolated organs and tissues actually maintain an autonomous rhythm of activity under certain conditions (for example, an extracted heart continues its rhythmic contractions at a certain rate, etc., of which we will speak in more detail). All these different rhythms in an organism are synchronized. The central nervous system is the regulating and synchronizing apparatus for the higher animals.

M. Breizet proposed the idea that the rhythmic activity of the brain, accompanied by certain bio-electric phenomena, plays the role of the synchronizer for all the processes in the central nervous system. According to many electrophysiologists (Winer, Guddi, Holubarg, Enlaiker, etc.), this rhythmic activity is also a standard of time of a certain rhythm to which the periodic functions of the cardiac activity, respiration, motor acts, etc., are compared. It is not coincidental that there are characteristics known as time series in electroencephalograms. It is possible that a change in the rhythmic activity of the brain could lead to shifts in the perception of time, and thus of its movements and the movements of the surrounding media.

In a science-fiction story entitled "Noveyshiy uskoritel" ("The Latest Accelerator"), H. Wells drew a picture about a change in the movements of his heroes and in their perception of the time aspects of the surrounding situations. Actually, something similar is found with certain malfunctions of the central nervous system, with the use of certain pharmacological substances, and with the effect of unusual stimuli on a human being. In this respect, the results of the observations by E.M. Bashkova and Ye. M. Zakhar'yanets of one young boy (12 years old) who had not suffered any deviations in the psychic field previously. After the onset of malaria, there were distinct changes in the sensory sphere. Every object seemed much smaller in size to this patient. He began to perceive speed incorrectly: everything seemed to be going more rapidly (for example, people were running, not walking). Therefore, he himself began to do everything very quickly. After treatment with quinine, /97
these phenomena disappeared.

Various studies have shown that there are electric potentials distributed according to a certain law on the surface of the body of animals and human beings. According to R. Becker, this distribution is caused by the directionality of the electron flux along the path of the nerve fibers. It was also suggested that the system of bio-electric potentials can interact with the oscillatios of the Earth's magnetic field. This hypothesis has been confirmed, in part, by the experiments the American biologist F. Brown conducted on cochleas. He showed that the behavior of the latter depended to a great extent on a change in the geomagnetic situations.

It is well known that the Earth's magnetic field "pulses" at a frequency of 8-16 oscillations per second. Based on this fact, certain scientists have proposed the idea that the presence of the principal rhythm of the brain's bio-electric potentials (the alpha-rhythm, which has the same frequency) is connected with the effect of this pulsation. Moreover, the Soviet scientist A. Presman has suggested that the periodically-changing geomagnetic field is the source of certain information. From this point of view, the increase in the number of neuropsychotics during magnetic storms, for example, can be explained in the following way. The chaotically-changing frequency of oscillations of the Earth's magnetic field can impose rhythms on the biological processes which are unusual to them, i.e., can introduce "harmful" information into an organism (according to Presman's expression). For a healthy person, the nervous system adapts well to changes in the surrounding medium. On the other hand, it becomes extremely sensitive to effects from outside when there is nervous exhaustion, or neural illnesses.

A weakened nervous system cannot cope with increased stress (including stresses from disturbances in the magnetic field), and the result is a nervous disorder or an aggravation of a previous illness.

One of the authors (V.I. Lebedev) proposed the idea that a change in the frequency of the rhythm of the brain's bio-electric potentials can affect a subjective estimation of time intervals. This was also indicated in certain experimental tests we conducted (V.I. Lebedev, O.N. Kuznetsov, A.N. Litsov, R.B. Bogdashevskiy).

The frequency of the alpha-rhythm for the subjects of these experiments was established according to their electroencephalograms. Various stimuli (light or sound) were given at the same frequency. Before this, the subjects reproduced time intervals at a signal against the background of an unchanged electroencephalogram. The accuracy with which the subjects estimated the time was recorded on a tape winder. Subsequently, the rhythm of the brain's bio-electric potentials became accelerated or retarded during the introduction of these stimuli. The subjects also reproduced time intervals against this changed background. It was found that, with an increase in the frequency of the rhythm of the brain's bio-electric potentials, the subjects underestimated the time interval; with a decrease in the frequency, they overestimated it. Thus, one of /98
the subjects reproduced a 20-second interval as 18.2 and 21.6 sec, respectively. The estimation of time intervals was particularly disordered during the "reductions" when the doctor applying the stimuli began to change (smoothly, then abruptly) the frequency of the alpha-rhythm during the evaluation itself. However, after introducing the corrections to the subjects, these people began to reproduce time intervals accurately even during the change in the rhythm of the bio-electric potentials of the brain.

In our opinion, the following conclusion can be drawn from all the above. The physical fields, including the geomagnetic field, affect the nervous system of animals and human beings in some way. It is very probable that the work of an organism's "biological clocks", the rhythm of which relates to the physiological processes, is connected with the pulsation of the geomagnetic field. In this case, we must keep in mind the problems which arise when astronauts go beyond the boundary of the Earth's magnetosphere. The lack of substantial magnetic fields on the Moon and certain other celestial bodies, the passage through powerful magnetic fields during space flights, and the encounter with rhythms of magnetic phenomena in outer space which are very different from those to which the astronauts are accustomed on the Earth, can affect the "biological clocks" in some way or another, which means that all these factors can affect the duration of the psychophysiological processes of a human organism. It is difficult to determine at this time to what degree the processes are affected. It is possible that these effects will be a real threat to the ordering of the "biological clocks" and will cause corresponding acute disorders in the psychophysiological functions. In that case, it will be necessary to find ways and means by which very intricate intra-organic processes can be interfered with, in order to regulate them artificially in the necessary direction, despite the disadvantageous situations. It is also possible that there will not be such disorders, since stable rhythms of biochemical reactions have been developed during the process of the evolution of terrestrial life; these rhythms could "cope" with the disorders in the rhythm of the electrophysiological spheres to a certain extent. In that case, the problem could be limited to only partial changes in the work of the "biological clocks" which could be mastered rather easily. In any case, it is now rather clear that a thorough study of the effect of the geomagnetic field and its changes, as well as the effects of a non-magnetic field, on the human organism (and on his reflection of the external world) must be put on the agenda in the plans for the development of science.

A SPACE-FLIGHT VIGIL AND THE PSYCHOPHYSIOLOGICAL RHYTHMS

We must understand what man is, what life is, what health is, and how the balance and harmony of poetry strengthens it, while discord destroys and ruins it.

Leonardo da Vinci

In the process of evolutionary development, plants and animals /99 have become adapted physiologically to periodic geophysical and meteorological changes connected with the rotation of the Earth around its axis and around the Sun (the onset of the light period of a day and of darkness, an increase in temperature and an increase in cosmic radiation in the daytime, a change in the humidity and barometric pressure of the air during the night, a shift in the season, etc.). One of the most characteristic modes of this adaptation is the diurnal rhythm of sleep and wakefulness. In relation to this, there is a decrease in the body temperature, the pulse and respiration, the metabolism processes, and other physiological functions of an organism during the night and their increase during the day. Even such phenomena as birth and death are subjected to diurnal periodicity. According to the data of F. Halberg, the greatest amount of births and deaths occur between 2300 and 0100.

During an orbital flight, there can be frequent shifts from day to night. For example, G.S. Titov encountered 17 "cosmic dawns" during the course of 24 hours. During an interplanetary flight, which could last many months and even years, the diurnal (and seasonal) periodicity to which man has become so accustomed on the Earth will not be observed at all. Finally, in landing on some celestial body, the alternation of day and night will also be greatly different from that of the Earth (for example, days last almost one month, according to the count used on the Earth, on the Moon). On the other hand, the astronauts will have to keep a flight vigil, conduct scientific investigations, maintain comunications with the Earth, etc., for which a certain organization of the times for labor and rest will be necessary. In relation to all this, we encounter the problems of the effects of disorders in the rhythms to which the astronauts are accustomed on their physiological functions and on the structure of the new optimum /100
rhythm for life activity on the interplanetary spacecraft.

The Diurnal Rhythms of Organisms.

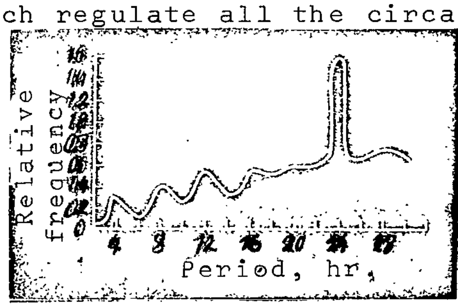
The astronomer de Meran, who was particularly interested in the rotation of the Earth around its axis, made a discovery in 1729. He found that plants cultivated in darkness and at a constant temperature have the same periodicity in the movement of their leaves as do plants cultivated under the conditions of alternate light and darkness. During the subsequent years, he continued experiments of this type with completely different organisms - from single cells to human beings. These experiments showed that living beings put in constant exposure to light (or darkness) maintain the rhythm of oscillations of activity and rest, growth, cell-division, etc. close to the 24-hour cycle. F. Halberg called rhythms with such periods "circadian" (from Latin words: "circo"-about, and "dies"-day).

Thus, a series of experiments was conducted with nocturnal flying squirrels. The animals were placed in a squirrel cage which was equipped with a device for recording the number of turns, and they were kept in complete darkness for several months. The graphs of the animals' activity, which were obtained with the aid of the squirrel cage, showed very clearly that they awakened every evening. They began running about in the cage after the same interval of time, roughly after one day each time.

In a series of experiments on mice, it was found that the same spontaneous frequency of oscillations of their physiological functions (motor activity, phases of sleep and wakefulness, etc.), which was close to a circadian rhythm, was maintained for six generations of these animals while they were kept constantly in light. Buning's information about the circadian oscillations which were maintained in an isolated section of the intestine of a hamster put in a physiological solution is no less interesting. There are also data about the circadian periodicity of cell division in tissue cultures of mammals.

Therefore, according to modern scientific theories, all plants and animals placed under so-called constant conditions show a physiological rhythmicity of the circadian type. The idea about the existence of "biological clocks" in organisms, on which the regulation of physiological processes depends, is also connected with this factor.

Obviously, the intracellular biochemical processes are the basis for the regulation of the circadian rhythms themselves in most single-cell organisms and plants. Their rhythmicity was developed during many millions of years of adaptation to the diurnal periodicity of day and night on our planet. We would like to emphasize that, in this respect, plants have no central mechanisms /101
which regulate all the circadian rhythms.



Distribution of the Number of Births at Various Times of the Day, Presented in the Form of a Periodogram.

The German scientist G. Kluck showed by special experiments that the regulation of the diurnal rhythm of the physiological functions in worms, arthropods, and other invertebrates is accomplished by the nervous system, particularly the subglossal ganglion.

The most specific data about the center which regulates the rhythm of motor activity during the course of a day were obtained by the English researcher Janet Harker in experiments with cockroaches (typical nocturnal insects). It was found that the role of the principal "biological clocks" of these insects is accomplished by the subglossal ganglion, which releases certain chemical substances. Thus, some cockroaches which had been under the conditions of continuous illumination and had lost a noticeably-pronounced rhythm for their motor activity were operated on: their subglossal ganglions were removed and replaced by other ganglions taken from rhythmically active cockroaches. After a few days, the activity of the insects which had been operated on became clearly rhythmical, and this rhythm corresponded to the rhythm of the cockroach-donor.

The physiological mechanisms for the circadian rhythm in higher vertebrates are particularly intricate. In this case, there are found simple regulators which are closely connected with metabolism, and complex time relationships which are coordinated by the cerebral cortex. These animals preserve a diurnal periodicity in sleep and wakefulness even after the cortex has been removed. The /102 diurnal rhythm of oscillations of their body temperature, metabolism processes, pulse frequency, blood pressure, respiration and other vegetative functions also remains the same after the removal of the cerebral cortex. It follows from this that the maintenance of the circadian rhythms involves the sphere of unconditioned-reflex activity, which is more resistant to random oscillations of the external medium, while the centers of the circadian regulation are found in the subcortical formations and the stem region of the brain.

We know from every-day experience that some people have an amazing ability to sense time. They can determine the hour of the day accurately and faultlessly, distinguish time intervals very well, establish the duration of pauses, etc. Since the astronauts in interplanetary flights will be affected primarily by constant conditions, but not by the geophysical effects to which they are accustomed, we now encounter another problem: to what degree will a human being be able to evaluate the circadian rhythm of his physiological processes, i.e., use his "biological clocks" in such a situation?

In this respect, it is of great interest to examine the observations of the expedition which went to the Arctic, where such a factor as the rising and setting of the Sun during the course of a day does not exist. The results obtained by M. Lobban, who conducted investigations at Spitsbergen during the period of a polar day, show that the continuous two-month daylight does not greatly affect the circadian rhythm of the physiological processes for people who came from middle latitudes.

It is well known that sound-proof chambers are used to imitate an interplanetary flight. They aid, not only in eliminating certain geophysical factors (change from daylight to night, natural noise, drops in the temperature and humidity of the air, oscillations of the radiation, etc.), but also in removing to some extent the effect of social surroundings.

F.D. Gorbov conducted the following experiment with a sound-proof chamber. His subject knew the duration of the experiment (7 days), but he had no clock or calendar. According to the instructions, he could go to sleep, eat, write notes in the log, exercise, etc. whenever he wanted. After a few days, the subject became disoriented in time, which was seen from his reports over the radio system. This subject showed a subjective speed-up of the passage of time. Thus, he prepared to leave the sound-proof chamber 14 hours before the designated time.

In his experiment, A. Achophe put a group of subjects in a specially equipped bunker far below the ground, which excluded the penetration of sounds. The subjects cooked their own food and were left entirely on their own. They turned off the light before going to sleep and turned it on when they woke up. The subjects were observed constantly with the aid of a special apparatus which /103
recorded their physiological functions. After 18 days, the subjects "lagged" behind astronomical time by 32.5 hours, i.e., their day consisted of almost 26 hours, not 24 hours. All their physiological functions also oscillated in this rhythm until the end of the experiment.

The experiments of certain speleologists, who used deep caves instead of sound-proof chambers, are also interesting. For example, Michel Siffre lived in one of the caves for 2 months in 1962. We can see from his reports that the experimenter soon "lost a sense of time..." under the conditions of solitude and a lack of communication with the outer world. After 1000 hours (more than 40 days), it seemed to him that only 25 days had passed. When this unusual experiment was ended and Siffre's friends came to get him, he announced the following: "If I had known that the end was so close, I would have eaten up all the tomatoes and fruits".

Three years later, this experiment was repeated by two scientists, Antoine Sonnie and his wife, speleologist Jusie Lorez. The young French speleologist Jean-Pierre Meretez lived under the ground for six months. However, we have not been able to find any materials which treat the perception of time and the diurnal rhythm of these experimenters.

In 1967, eight Hungarian researchers lived under the ground in one of the caves of the Budai Mountains for about one month. The members of this expedition had no watches or radios. When they were given the command (by telephone) to climb back up to the surface, it was found that the readings of time made in the cave were four days slower than the actual time. In this case, the "biological clocks" of all the members of the expedition were synchronized during the first 10 days, but then discrepancies began to appear in their time orientation.

We can conclude from the above that, although the physiological processes of a human being continue to maintain a circadian rhythmicity for a certain length of time under constant conditions, orientation without "time devices" does not seem feasible.

Space Vigil

Considering what we have said about the circadian rhythms of the psychophysiological processes, it seems that it would be necessary for the crew of prolonged interplanetary fights to preserve the usual rhythm of terrestrial days. However, this is probably impossible.

We have already mentioned that the astronauts will be included in the system "astronaut - automatic devices" while steering the interplanetary craft during a long flight. The principal function of the operator in this system is the observation of the indications of the instruments (under normal circumstances). However, the activity of the astronaut will differ from the normal operating activity of, say, someone observing the control panel of a modern electric power station. The operator of the spacecraft will be required to accomplish certain regulating functions at the same time; these regulations can be connected with fields of science and /104
technology which are hardly related. For instance, the control of the working apparatus of a closed or half-closed ecological cycle requires a knowledge of biology, while the control of a flight regime of trajectory requires astronomical and navigational knowledge. In general, the functions of the operator-astronaut will include a compensating watch of many indicators, operations for supervising the values of the regulated parameters of an object, mathematical and logical analyses of the information coming from the instruments and apparatus, generalization of the results of the control and comparisons between these results and the program, development of solutions by which an object can be regulated, and accomplishment of these solutions.

We must emphasize the idea that, during a prolonged space flight, it is very possible that some instruments and systems could go out of order and that unforeseen complications could arise. This would mean that the astronaut would be required to transfer from observations to actions. In general, it is practically impossible to foresee all the variations in the operation of mechanisms, malfunctions, and emergency situations which could occur. Moreover, only the intelligent responses of a man who has knowledge and experience can manage unexpected and accidental situations satisfactorily. Therefore, the astronaut who is keeping the watch must always be prepared to act. The effectiveness of his interference into the course of events depends on his preparedness. In the language of cybernetics, the operator-astronaut must fulfill the role of the "waiting circuit". This preparedness for action is an important factor in the reliability of the astronaut as the link in the system "astronaut - automatic devices". This brings about the urgent need for the crew members on the interplanetary craft to keep a vigil.

How long can the astronaut who is keeping the watch be alert and ready for action? In other words, when will he show fatigue which is reflected in the quality of his operating activities? At the present, it is impossible to answer this question with absolute certainty. However, using the data of physiology and the psychology of labor, scientists can now find the means by which they will be able to determine the optimum length of time for keeping a watch during a space flight.

While characterizing the process of labor, K. Marx wrote the following: "Besides the tension of those organs by which a work is performed, a purposeful will, expressed in attention, is also necessary during the entire time of the work. It is all the more necessary when the labor does not require a great deal of action..." (Das Kapital, Vol. I, p. 185). Of all the different qualities of attention, the most occupationally significant are the following: intensity (or concentration), stability, the rate of shifting attention, and the scope. It itself is "brought about by that organization of activity for which certain perceptions, thoughts /105 or senses are recognized very clearly, while others are given second place or are not recognized, consciously, at all" (K.K. Platonov, 1962, p. 41).

The great intensity of attention during the entire course of the vigil is the characteristic feature of the operator's function in the automatic systems. Motor acts are much less significant for this function. However, even K. Marx mentioned that "continuous monotony of a work weakens the intensity of attention and energy reserve, since the worker has neither rest nor excitation, which factors are developed by a change in activity" (Das Kapital, Vol. I, p. 348). This concept was confirmed by special experiments and by investigations of the nature of the labor processes for those who have so-called observational professions.

For example, V.V. Suvorova, Yu. V. Idashkin and S.S. Gadzhiyev investigated the duties involved at modern electric power stations; they found that even those duties during which the staff do not execute any operations and are occupied only with observations and anticipations of accidental disorders (which seemed easy at first glance) lead to exceptionally great nervous tension. At the end of the shift, the operators seem to be incapable of any intellectual activity, they sleep poorly, their excitability is greatly increased, etc. Numerous tests conducted by Soviet and foreign scientists have shown that, after 5-6 hours of observations, particularly when the automatic devices operate normally, the alertness of the observer gradually decreases. Thus, his reliability in the system "human being - automatic devices" also decreases. Researchers have also found that negative emotions also greatly affect the process of becoming fatigued.

When we consider that many disadvantageous factors (including the long duration of the flight) will act on the astronaut, it becomes obvious that fatigue will develop before 5-6 hours during a space vigil. Therefore, the optimum time for his work under these conditions seems to be a period which does not exceed four hours (with rest and sleep beforehand obligatory). This conclusion has been confirmed to some extent by the practice of long submarine voyages, when each sailor kept a four-hour watch.

Space Days

During the first interplanetary flight, the number of crew members will assumedly be small. Therefore, it will be difficult (if not entirely impossible) to organize four-hour vigils during the course of terrestrial days. However, we can see a way out of this situation when we think along the lines of a change in the /106 duration of a day, a change in the rhythm of the life activity for the people on the interplanetary craft.

Let us turn first of all to the facts which were obtained by the study of labor and connected with the effect of work during various times of the day on the psychophysiological processes. V.P. Solov'yeva and G.M. Gambashidze conducted observations with subway workers who had been working only night shifts for a long period of time (from 6 to 22 years). These scientists investigated their body temperature, pulse frequency, blood pressure, attention span, and other psychophysiological phenomena. They found that, despite the long years of work solely during the night, there were no rearrangements of the diurnal rhythm of the physiological functions in almost all of the subjects. The principal changes of the latter had a sinusoidal nature, with a maximum during the day (1200-1600), i.e., when the subjects rested, and with a minimum during the night (0200-0400), i.e., when the subjects worked. In other words, their curves coincided mainly with the famous classic curves obtained for people who sleep and wake at normal times.

In order to study the psychophysiological changes affected by eight hours of work during night, evening, and day shifts for linotypists, G.P. Volkhina and R.I. Kryuk studied the condition of their attention according to the method of standardized tables. They also determined the marginal sensitivity of the auditory organs and other functions. They found that the lowest data, according to the tables, were obtained for the night shift, and the highest figures for the day shift. The functional changes during one evening shift held a middle position. In other words, there were also no rearrangements in the psychophysiological functions because of night work.

E.I. Brant and O.I. Margolina studied engineer-and conductor-crews accompanying freight trains. The days were broken up into alternate periods of sleep and work for these people, but there was no strict schedule (or many different schedules). In other words, their work was a typical example of a breach in the diurnal stereotype. The observations showed that, during many years of such an unusual alternation of work and rest, the organism becomes adapted to the lack of a constant regime. This adaptation was expressed in the ability of the engineers and conductors to fall asleep very quickly during any time of the day, even when a sleep-period at a "stop" preceded a normal night's sleep at their homes. However, even this situation did not change the normal curves for the diurnal oscillations of their physiological functions.

We can see that geophysical factors (daylight, etc.) as well as social surroundings (the rhythm of family-life, the work of governmental establishments, contact with friends, etc.) have much less significance for a human being than his own rhythms for work, /107
rest, eating, etc.

The act of thinking plays a very important role in the accomplishment of the physiological functions; it aids in determining the relationship to the passage of time (for instance, in an illuminated subway station during the night).

It is fitting to discuss here the observations with people who flew to various regions of the Earth and encountered a time-change of 6-12 hours. By the effect of the altered rhythm of the geophysical factors and of the life of the surrounding people, these subjects showed a rearrangement of their physiological processes in relation to the new conditions of existence after a few days (normally no longer than 15 days). At the same time, we have already seen that no such rearrangement occurs for those whose day-schedules are altered, but whose surrounding medium remains the same, even during the course of many years.

A large quantity of experiments have shown that a rearrangement of the rhythm for the physiological functions of plants and animals is caused mainly by the effects of light and temperature. Although living organisms are capable of maintaining a circadian rhythm, this does not mean that its frequency must remain constant under all conditions. Actually, an organism is an "open system", and it is always affected by the surrounding medium and constantly adapting to these changes. Such factors as light and temperature, in particular, serve as unique time counters under terrestrial conditions. They seem to be signals for the synchronization of the circadian rhythm of the physiological functions with astronomical time.

I.P. Pavlov showed that, the more complexly an animal is structured, the more quickly and effectively it can adapt to changing conditions in the external medium. This adaptation is accomplished by means of a formation of time relationships in the cerebral cortex. With the aid of the mechanism for conditioned reflexes, the unconditioned-reflex activity, which includes the circadian rhythmicity of the physiological functions, also adapts to a changing situation. Pavlov held that "the most general characteristic of a living being is that it responds to external stimuli (the relationship to which it was prepared for since the moment of its birth) as well as many other stimuli (the relationship to which it developed during the course of individual existence) by certain specific activity. In other words, a living being is capable of adapting" (1951-1952, Vol. 3, pp. 77-78).

In examining the adaptation of the physiological functions of higher animals to changes in the rhythms of life activity, the experiments O. P. Scherbakova conducted on monkeys are very valuable. These experiments were conducted during the course of one year in a specially equipped building with artificial lighting. The physiological functions of the monkeys were investigated during two-phase, shortened, extended, and other diurnal regimes. It was /108
found, for example, on the third day of a two-phase diurnal rhythm, that the motory activity of most of the monkeys had a corresponding rhythm; on the sixth to thirteenth day, there were two phases in the curves for their body temperature, pulse frequency, respiration, and other physiological processes.

With a development of space technology in the Soviet Union and in foreign countries, scientists began to conduct experiments in order to study various regimes of diurnal activity under conditions which imitated a space flight. In our country, the pioneers in this field were the collective headed by F.D. Gorbov.

We (O.N. Kuznetsov, V.I. Lebedev and A.N. Litsov) conducted experiments under the conditions of a sound-proof chamber in order to study "reversed" (wakefulness during the night and sleep during the day), fractional, and other regimes. The studies were executed in complete solitude, with isolation from external light and sound stimuli, and with an absence of two-way communication. Men from 26 to 38 years old took part in the experiment. They underwent a complete clinical investigation preliminarily. We set up a strict schedule for the subjects: it included accomplishment of operating activities, active rest periods, and sleep. With the two-phase rhythm, the subjects accomplished everything twice a day; with the three-phase rhythm, they carried out everything three times.

The results of the experiments showed that, the more a man's life activity deviates from the one to which he is accustomed, the more difficult it is for him to tolerate all the effects. The three-phase rhythm was particularly difficult. In general, the subjects recovered the initial level for their working capacity on the second to fifth day of a shift from the normal regime to a new one, and they began to fall asleep at the times designated by the new schedule. However, the corresponding rearrangement of the vegetative functions (pulse, respiration, body temperature, metabolism, etc.) occurred only on the eighth to fifteenth day, and was not always completed even at the end of the fifteenth day. Of all the altered regimes which we and Gorbov studied, the most acceptable one, obviously, was divided into two sleep-periods. On the other hand,none of the subjects noticed the finish of a cycle subjectively during this rhythm. They continued to count time according to normal terrestrial days. In all probability, the time read on board an interplanetary craft will also be Moscow time. This system for reading time has already been encountered by many people living on our planet. For example, the citizens of Vladivostok, who live according to their local time, necessarily compare it to Moscow time.

For animals, the physical factors (light, temperature, etc.) are of principal significance in the rearrangement of the diurnal regime; for humans, the psychic activity, the will power to accomplish the schedule of a day, and the ability to reorganize rapidly /109
in relation to a change in a situation are essential, as O.N. Kuznetsov has justly pointed out. We found that the adaptation of the physiological functions to a new rhythm is particularly difficult for those people who tried constantly to find out what was occurring outside the sound-proof chamber.

We must assume that the number of crew members, the amount of work, the presence of accommodations for resting, etc, will be considered in working out the schedule for each concrete interplanetary flight. It is possible that the rhythm of space days will have the following appearance: 4 hours of operating activities, 4 hours of active rest, and 4 hours of sleep. During the period of active rest, the astronauts are not limited to physical exercises. In order to eliminate fatigue, a rationally organized change in the type of activity is necessary. Therefore, it is probable that part of the time after the vigil will be spent in scientific experiments, in generalizing the results obtained, etc.

A change in emotional conditions has great significance in the working capacity of the astronauts. I.M. Sechenov has shown that animation, music, etc. can be important factors here. Doubtlessly, the astronauts will watch specially selected color films, hear musical compositions which have been recorded, and read books. Extra-long-range television and radio transmissions could play a very important role. With the aid of these media, the astronauts could follow the course of life on the Earth constantly, "attend" the theatre, the movies, or a sports arena, and communicate with their friends and relations.

It is important that all the members of the crew (or at least the majority) will eat at the same time, and that their active rest periods will not occur in solitude, as a rule. The intracollective contacts will affect the level of the nervous system and the moods of the astronauts in a very favorable way.

It is well known that the intensive work of the brain during wakeful hours, its constant reaction to innumerable stimuli of the external medium lead to the exhaustion of many cells in the cerebral cortex. The restoration of their working capacity occurs during sleep-periods. That is why it will be necessary to create conditions on the interplanetary craft in which the astronauts will be able to have fully adequate sleep.

The eight-day flight of the "Gemini 5", an American craft, showed that it is very difficult to sleep in turns in the room where operations are being accomplished. The astronauts G. Cooper and C. Conrad, who lived on such a schedule, complained that the least noise alarmed them, even that of turning the page of the on-board diary, since it was generally very quiet in the cabin. We can see that it will be necessary to install special sleeping quarters on an interplanetary craft. If sounds nevertheless penetrate in these /110 quarters and interfere with the astronauts' sleep, it is feasible that "sound props" will be produced, i.e., a monotonous sound or a noise similar to the sound of an ocean tide, rain and wind, etc. This noise could muffle the undesirable sound phenomena and aid the astronauts in falling asleep. But this problem is not solved completely by special quarters and sound isolation. The astronauts must develop in themselves the ability to fall asleep quickly when necessary. This ability was found, for example, during the sound-proof chamber experiments, with Yu. A. Gagarin. He showed an ability to "unwind" even during the short pauses designated as rest-periods, falling asleep instanteously, and waking himself up at the designated time.

As our studies have shown, four hours of sleep after eight hours of wakefulness allows a man to recover his working capacity completely in a sound-proof chamber. Therefore, it is important that strictly constant hours for watches, rest, and sleep be established for each crew member on a spacecraft. Doubtlessly, further experiments on the Earth and in orbital flights will aid in clarifying and developing the optimum rhythms for space days.

CONCLUSION

Even during the dawn of aerial navigation, K.E. Tsiolkovskiy wrote the following: "I believe in the brilliant future of mankind. I believe that mankind not only will populate the Earth, but also will transform the world of the planets. From here, from the sphere of the Sun, mankind will begin to penetrate the entire Universe. I am deeply convinced of this. This is the destiny of terrestrial man. He must transform many planatary systems." /111

The scientific predictions of this founder of astronautics are now beginning to come to pass. Mankind is preparing to make more and more advances in the great conquest of outer space. The scope of complex scientific and technological problems is expanding, and thousands and thousands of scientists, designers, engineers, and technologists are working on these problems.

One of the problems is the establishment of the capacities of a human being to perceive time and space outside the Earth. We have attempted to generalize certain scientific materials which treat a few aspects of this problem. There is still a great deal of research to be done. The problems of perceiving space and time during flights at the speed of light, in themselves, are almost untouched. However, there is no doubt that, no matter what difficulties await those who are taking part in this conquest of outer space, all the obstacles will be overcome, and the cosmic future of mankind will become a fact.

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